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(Proceedings)

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MESSAGE

THE PRESIDENT OF THE UNITED STATES

TO THE SENATE

IN COMPLIANCE WITH A RESOLUTION OF THE SENATE OF JULY 21, 1857

FOR

FOURTH METEOROLOGICAL REPORT

BY

Prof. JAMES P. KIPP

Printed by the Government Printer, Washington, D.C.

WASHINGTON:

A. O. P. MORGAN, PRINTER.

1857

1852

THE PRESIDENT OF THE UNITED STATES

IN COMMISSION WITH A CERTIFICATE OF THE SECRETARY OF THE INTERIOR

FOURTH METEOROLOGICAL REPORT

By JAMES P. EBBE

WASHINGTON

MESSAGE

FROM

THE PRESIDENT OF THE UNITED STATES,

COMMUNICATING,

IN COMPLIANCE WITH A RESOLUTION OF THE SENATE OF JULY 24, 1854,

THE

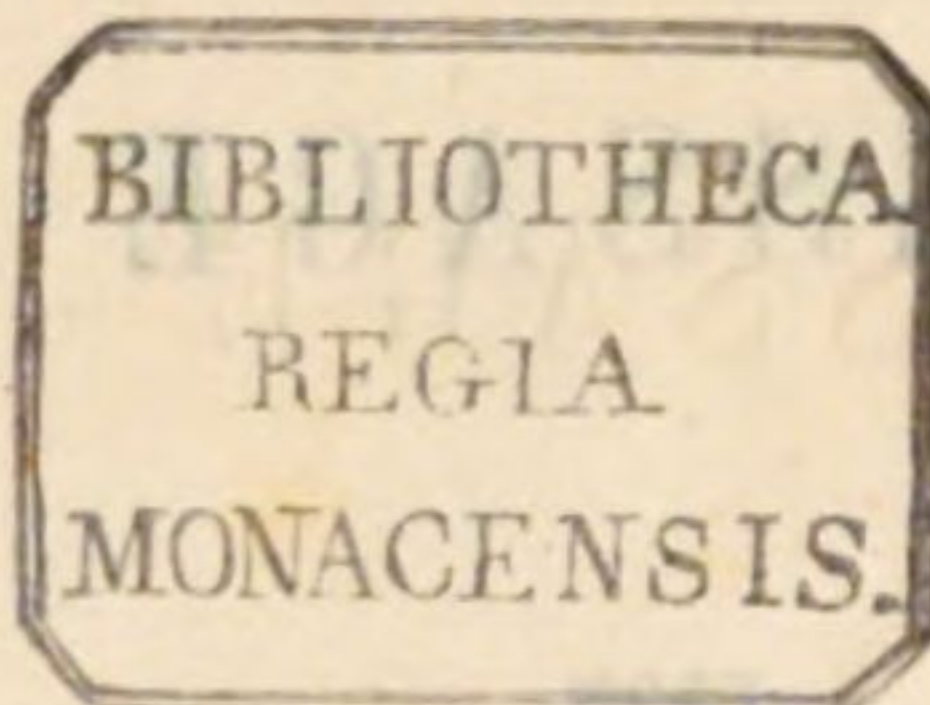
FOURTH METEOROLOGICAL REPORT

OF

PROF. JAMES P. ESPY.

FEBRUARY 28, 1857.—*Ordered*, That 3,000 copies thereof be printed, in addition to the usual number, with seventy of the maps accompanying the same.

WASHINGTON:
A. O. P. NICHOLSON, PRINTER.
1857.



THE PRESIDENT OF THE UNITED STATES

COMMUNICATION

BY COMMISSIONER WITH A RESOLUTION OF THE SENATE OF JUNE 20, 1861.

THE

FOURTH METEOROLOGICAL REPORT

OF

PROF. JAMES P. ESBY.

WASHINGTON: PUBLISHED BY THE NATIONAL BUREAU OF METEOROLOGY, IN ADDITION TO THE ANNUAL REPORT, WITH RESULTS OF THE INVESTIGATION OF THE CAUSE OF THE DROUGHT OF 1861.

WASHINGTON:
A. O. T. KIRKMAN, PRINTER.
1861.

ERRATA FOR J. P. ESPY'S FOURTH REPORT ON METEOROLOGY.

Page 125, near bottom, for "above there mean," read "above the mean there."

Page 42, for "b," at the barometer gauge of small vessel, read "f."

Page 118, for "would heat that water 48° ," read "would heat that water 12° ."

Page 27, for "422.4 feet greater than," read "422.4 feet less than."

Page 147, after paragraph ending with these words: "from $43^{\circ}.5$ to 58° Fahrenheit," insert: "The N.W. wind of this district resembles the sirocco of the Mediterranean; it comes on suddenly, and raises the temperature in a few minutes from 12 to 20 degrees. It is a matter of surprise and speculation that these hot N. W. winds, proceeding directly from the snow, should produce considerable heat . . . nor can it be accounted for by the air traversing the plains, as the heat is found fully as sensible, and perhaps more so, at the foot of the snowy range."—(See first number of Meteorological Papers, published by authority of the Board of Trade, London; page 71-73. Commander Byron Drury, on New Zealand, where he spent several years.)

Page 215, for "as between," read "running out both ways at the base."

FOURTH METEOROLOGICAL REPORT.

BY JAMES P. ESPY.

To the President of the Senate :

In compliance with the resolution of the Senate of the 24th instant, requesting me to cause to be transmitted to the Senate the Fourth Meteorological Report of Professor Espy, the accompanying papers and charts are respectfully submitted.

FRANKLIN PIERCE.

WASHINGTON, *July 27, 1854.*

REPORT.

1. In this *report*, as in the preceding ones, I have collated all the meteorological journals placed at my disposal, and laid down, on skeleton charts of the United States, by appropriate symbols, the most important phases of the great storms which come within the range of our simultaneous observations, that, by these means, we may be enabled to determine the *shape* and *size* of all great storms; whether they are *round* or *oblong*, and if oblong, whether they move *side foremost* or *end foremost* or *obliquely*, and their *velocity* of motion, and the direction which they take in all the different seasons of the year; the *course* that the wind blows in their borders, the *fluctuations of the barometer* which accompany storms, and the *extent* to which the influence of storms is felt beyond their borders.

2. Wishing to return my hearty thanks to those amateurs of the science who assisted me in this undertaking in the early part of my labors, I here repeat the list of observers given in my second report.

3. List of early meteorological correspondents.

3. LIST OF METEOROLOGICAL CORRESPONDENTS.

- Francis Adams, Knoxville post office, Green county, Ala.
 Professor William H. Allen, Carlisle, Pennsylvania.
 Zeno Allen, Sackett's Harbor, New York.
 Dr. D. Alter, Freeport, Pennsylvania.
 Thom. Anderson, Louisville, Kentucky.
 Professor J. W. Andrews, Marietta, Ohio.
 R. F. Astrop, Diamond Grove, Virginia.
 S. Aylsworth, Utica, New York.
 L. H. Anderson, M. D., Sumpterville, Alabama. (Wishes to purchase a barometer.)
 Thom. Bailey, Little Compton, Rhode Island.
 Joshua Bartlett, East Thomaston, Maine.
 Dr. E. Barton, New Orleans.
 O. Beatty, Danville, Kentucky.
 E. W. Beans, West Chester, Pennsylvania.
 Henry W. Beecher, Indianapolis, Indiana.
 Charles F. Barker, Jonesport, Washington county, Michigan.
 G. A. Bliss, Long Meadows, Springfield, Connecticut.
 Lewis M. Booth, Quincy, Illinois.
 Dr. J. P. Batchelder, Utica, New York.
 Rob. Banning, Isthmus, Talbot county, Maryland.
 John F. Blake, Brewer, Maine.
 G. F. Blatzell, Apalachicola, Florida.
 S. Boyden, Newark, New Jersey.
 W. H. Boyle, Chambersburg, Pennsylvania.
 Thom. Brown, Cambridge, Ohio.
 B. B. Brown, St. Louis, Missouri.
 Amos J. Bruce, Fort Snelling.
 J. C. Bryant, Cambridge, Vermont.
 M. K. Brownson, Juliet, Will county, Illinois.
 E. W. Carpenter, Chatham, Massachusetts.
 Professor P. Carter, Granville, Ohio.
 Professor A. Caswell, Providence, Rhode Island.
 Professor James H. Coffin, Williamstown, Mississippi.
 Professor C. Collins, Emory and Henry College, Virginia.
 H. A. Coffin, Edgartown, Massachusetts.
 James F. Cogswell, Mellville, Orleans county, New York.
 Michael Clear, Philadelphia, Pennsylvania.
 Cornelius Chase, Chatham, Columbia county, New York.
 R. L. Cooke, Bloomfield, Essex county, New York.
 Professor G. H. Cook, Troy, New York.
 L. E. Corson, Norristown, Pennsylvania.
 John R. Cotting, Milledgeville, Georgia.
 John Clement, jr., Haddonfield, Gloucester county, N. Jersey.
 Lyman W. Conkey, Syracuse, New York.
 James Crosby, Marietta, Ohio.
 Wm. Crawford, Halifax, Nova Scotia. (Care of Th. Green-let, Boston, Massachusetts.)
 Dr. E. H. Davis, Chillicothe, Ohio.
 Professor Deems, Chapel Hill, North Carolina.
 Rev. G. Duffield, Detroit, Michigan.
 A. K. Eaton, Clinton, New York.
 Dr. Geo. Engleman, St. Louis, Missouri.
 Professor Jacob Ennis, Patterson, New Jersey.
 John F. Fisher, York, Pennsylvania.
 Dr. H. K. W. Ford, Cottage Malcomb, Jefferson county, Mississippi.
 Professor Ford, Hudson, New York.
 Ch. J. Fox, Nashville, New Hampshire.
 Professor James Garvin, Knoxville, Tennessee.
 R. H. Gardiner, Gardiner, Maine.
 Professor Gibbes, Charleston, South Carolina.
 Professor Giraud, Emmitsburg, Maryland.
 Rich. T. Gibson, Savannah, Georgia.
 E. Giddings, Lockport, New York.
 Professor C. Gill, Flushing, New York.
 Thom. F. Javmore, Whiteville, Hardeman county, Tenn.
 A. D. Galt, Williamsburg, Virginia.
 James H. Greene, Washington, Michigan.
 Trail Green, Mercersburg, Pennsylvania.
 Ch. Grant, Frederica, St. Simon's, Georgia.
 Professor James Hamilton, Nashville, Tennessee.
 James C. Hatfield, Lebanon, Ohio.
 Rufus Haymond, Brookville, Franklin county, Indiana.
 C. M. Harancourt, Columbus, Ohio.
 Jedediah Herrick, Hampden, Penobscot county, Maine.
 A. W. Hendry, Angola, Steuben county, Indiana.
 F. G. Hoover, Emmitsburg, Maryland.
 Dr. J. Heisley, Harrisburg, Pennsylvania.
 Th. Hoxie, Leonardsville, New York.
 N. W. Hatch, Vicksburg, Mississippi.
 A. W. Hendry, Sandusky city, Ohio.
 Professor N. W. Hentz, Tuscaloosa, Alabama.
 John Hunt, Bennington, Vermont.
 Edward P. Huntington, Cabotville, Massachusetts.
 A. M. Hunt, Greensburg, Indiana.
 Gustavus A. Hyde, Framingham, Massachusetts.
 Franklin B. Hough, A. M., Martensburg, New York.
 Edward Jarvis, St. John, New Brunswick.
 O. Jennings, East Troy, Wisconsin.
 Professor M. Jacobs, Gettysburg, Pennsylvania.
 Dan. Jagger Warren, Trumbull county, Ohio.
 John F. Jenkins, N. Salem, New York.
 James M. Jackson, Clarksburg, Virginia.
 Jos. Johnson, M. D., Shawneetown, Illinois.
 Tho. H. Kelsey, Jamaica, New York.
 — Kennedy, Columbus, Ohio.
 Jas. A. Kinkead, Mifflintown, Pennsylvania.
 M. Z. Kreider, M. D., Lancaster, Ohio.
 Professor J. G. Kummer, Bethlehem, Pennsylvania.
 J. A. Lapham, Milwaukee, Wisconsin.
 Hen. Leech, Vermont, Illinois.
 Richard Lewis, Ebensburg, Pennsylvania.
 Captain J. H. Lefroy, Toronto, Canada West.
 Rev. J. H. Linsly, Stratford, Connecticut.
 Nathan Linton, Upper Oxford, Chester county, Pennsylvania.

John A. Lyle, M. D., Paris, Kentucky.
 D. J. Lake, Mount Morris, Livingston county, New York.
 Professor Jas. P. Mason, Athens, Ohio.
 Professor W. W. Mather, Athens, Ohio.
 D. P. Mayhew, Lowville, New York.
 Wm. Merrill, Owensboro', Davis county, Kentucky.
 Professor C. F. McCoy, Athens, Georgia.
 W. S. McMurtry, M. D., Benton, Mississippi.
 John J. McRae, Jackson, Mississippi. (Care of F. S. Hunt.)
 Andrew MacKinley, Halifax, Nova Scotia. (Care of B. & W. Noyes, Boston.)
 L. Merrill Miller, Mount Morris, New York.
 Professor O. W. Morris, Deaf and Dumb Institute, New York.
 F. S. Monroe, Taunton, Massachusetts.
 G. R. Morton, Sandusky city, Ohio.
 Silas Meacham, Chicago, Illinois.
 Professor W. A. Norton, Newark, Delaware.
 Joseph G. Norwood, M. D., Madison, Indiana.
 Henry S. Osborn, Coventry, Rhode Island.
 Sam. Oswald, New Market, Shenandoah county, Virginia.
 James Primrose, United States consul, Pictou, Nova Scotia.
 J. D. Parker, Steuben, Maine.
 Reuben Parker, Blue Hill, Maine.
 W. R. Patterson, Wirt Seminary, Tennessee.
 David Peelor, Indiana, Pennsylvania.
 H. C. Perkins, Newburyport, Massachusetts.
 William Peters, Zanesville, Ohio.
 Z. M. Phelps, Yellow Springs, Green county, Ohio.
 James Phillips, Chapel Hill, North Carolina.
 W. W. Phillips, Edwards' Depot, Hinds county, Mississippi.
 A. Putnam, Grafton, Vermont.
 Sam. Plant, Northampton, Massachusetts.
 James E. Pierce, Black Meadows or Sandy Spring, Maryland.

F. S. Parvin, Bloomington, Iowa.
 Dr. J. T. Peebles, Petersburg, Virginia.
 Henry Poole, agent of Albion Mines, Pictou, Nova Scotia.
 Samuel Rodman, New Bedford, Massachusetts.
 Thomas A. Russell, Greenville, Tennessee.
 Dr. J. G. Sanborn, Carlyle, Clinton county, Illinois.
 J. E. Seaman, Paulding county, Mississippi.
 Dr. W. Kemble Salter, Rensselaer, Jasper county, Indiana.
 Sam. H. Stout, Eaton, Gibson county, Tennessee.
 F. C. Stokes, Stroudsburg, Monroe county, Pennsylvania.
 James J. Strang, Randolph, New York.
 Titus Smith, Halifax, Nova Scotia. (Care of Thom. Green-let, Boston.)
 Philo Taylor, Cleveland, Ohio.
 Joseph Templeman, St. John, Newfoundland. (Care of Messrs. Stokes & Anthony, New York.)
 Rev. Sereno Taylor, Glennville, Barbour county, Alabama.
 Professor H. Tutwiler, La Grange College, Alabama.
 Dr. Th. S. Williamson, Lac-qui-Parle, 150 miles west of Fort Snelling.
 John H. Webb, Adams, New York.
 Milo G. Williams, Dayton, Ohio.
 H. D. White, Hindman, Cumberland county, Maine.
 Sam. Webber, M. D., Charlestown, New Hampshire.
 Professor S. R. Williams, Canonsburg, Pennsylvania.
 John Wass, Addison, Maine.
 Geo. A. Wheelock, Keene, New Hampshire.
 William B. Williams, Dover, Tennessee.
 Charles Wister, jr., Germantown, Pennsylvania.
 G. H. Wood, Franklin Academy, Malon, Franklin county, New York.
 W. B. Williams, New Concord, Calloway county, Kentucky.
 Aaron Young, Bangor, Maine.

LIST OF PERSONS FROM WHOM METEOROLOGICAL OBSERVATIONS HAVE BEEN RECEIVED AT THE SMITH-SONIAN INSTITUTION DURING THE YEAR 1852.

Rev. Samuel H. Merrill, Oldtown, Maine.
 George B. Barrows, Fryeburg, Maine.
 James G. Garland, Biddeford, Maine.
 Rufus Buck, Bucksport, Maine.
 S. A. Eveleth, Windham, Maine.
 Joshua Bartlett, Whitehead, Maine.
 J. D. Parker, Steuben, Maine.
 Christopher Prince, Thomaston, Maine.
 John J. Bell, Cannel, Maine.
 Dr. William Prescott, Concord, New Hampshire.
 Robert C. Mack, Londonderry, New Hampshire.
 Rev. Levi W. Leonard, Dublin, New Hampshire.
 Samuel N. Bell, Manchester, New Hampshire.
 Rev. Zadock Thompson, Burlington, Vermont.
 Professor W. H. Parker, Middleburg, Vermont.
 Lewis M. Dayton, Castleton, Vermont.
 D. Underwood, Castleton, Vermont.
 David Buckland, Brandon, Vermont.
 Jacob Batchelder, Lynn, Massachusetts.
 Samuel F. Haven, Worcester, Massachusetts.
 William Bacon, Richmond, Massachusetts.
 Amasa Holcomb, Southwick, Massachusetts

Henry Rice, North Attleboro', Massachusetts.
 C. M. Freeman, Williamstown, Massachusetts.
 Benjamin R. Gifford, Barnstable, Massachusetts.
 Professor A. Caswell, Providence, Rhode Island.
 Rev. T. L. Edwards, New London, Connecticut.
 Professor Aug. W. Smith, Middletown, Connecticut.
 P. A. Chadbourne, East Windsor Hill, Connecticut.
 L. F. Munger, Albion, New York.
 C. F. Maurice, Sing Sing, New York.
 E. A. Dayton, Madrid, New York.
 Dr. Franklin B. Hough, Somerville, New York.
 John Bowman, Baldwinsville, New York.
 Walter D. Yale, Houseville, New York.
 J. E. Breed, Smithville, New York.
 Ephraim N. Byram, Sag Harbor, New York.
 John Lefferts, Lodi, New York.
 John P. Fairchild, Seneca Falls, New York.
 Charles A. Avery, Seneca Falls, New York.
 John F. Jenkins, Salem Centre, New York.
 Albert Hosmer, Fort Porter, New York.
 J. M. Hart, Oswego, New York.
 Mandrin Linus, Sackett's Harbor, New York.

- James B. Trevor, Lockport, New York.
 William E. Guest, Ogdensburg, New York.
 Henry L. Dinsmore, Syracuse, New York.
 Thomas B. Arden, Phillipstown, New York.
 L. L. Fairchild, Constableville, New York.
 Dr. P. O. Williams, Gouverneur, New York.
 Professor A. D. Frost, Burlington, New Jersey.
 R. L. Cooke, Bloomfield, New Jersey.
 W. A. Whitehead, Newark, New Jersey.
 W. O. Blodget, Sugar Grove, Pennsylvania.
 Professor M. Jacobs, Gettysburg, Pennsylvania.
 Joseph Edwards, Lima, Pennsylvania.
 J. L. Miller, Lima, Pennsylvania.
 Rev. J. G. Ralston, Norristown, Pennsylvania.
 John Jackson, Darby, Pennsylvania.
 Andrew Roulston, Freeport, Pennsylvania.
 David Peelor, Indiana, Pennsylvania.
 Corydon Marks, Manchester, Pennsylvania.
 Dr. R. P. Stevens, Ceres, Pennsylvania.
 Dr. Paul Swift, Philadelphia, Pennsylvania.
 Ebenezer Hance, Morrisville, Pennsylvania.
 E. T. Kluger, Nazareth, Pennsylvania.
 E. Kummer, Nazareth, Pennsylvania.
 Dr. J. Heisely, Harrisburg, Pennsylvania.
 Orrin T. Hobbs, Randolph, Pennsylvania.
 M. H. Cobb, Honesdale, Pennsylvania.
 Dr. Henry Smyser, Pittsburg, Pennsylvania.
 W. W. Wilson, Pittsburg, Pennsylvania.
 John Comly, Byberry, Pennsylvania.
 Francis Schreiner, Kingsley's P. O., Pennsylvania.
 Professor J. A. Kirkpatrick, Philadelphia, Pennsylvania.
 Rev. David J. Eyler, Somerset, Pennsylvania.
 J. Fisher Coorlies, Philadelphia, Pennsylvania.
 M. Abbott, Summit Hill, Pennsylvania.
 Thomas Seabrook, Summitville, Pennsylvania.
 Samuel Brown, Bedford, Pennsylvania.
 Barnet McElroy, Clarksburg, Pennsylvania.
 Professor E. D. Porter, Newark, Delaware.
 Dr. William Baer, Sykesville, Maryland.
 Dr. Lewis F. Steiner, Baltimore, Maryland.
 Henry E. Hanshew, Frederick, Maryland.
 Lewis J. Bell, Leitersburg, Maryland.
 Rev. John P. Carter, Hagerstown, Maryland.
 Professor J. P. Nelson, New Windsor, Maryland.
 Smithsonian Institution, Washington, District of Columbia.
 Dr. F. J. Mettauer, Prince Edward C. H., Virginia.
 William Skeen, Huntersville, Virginia.
 Lieut. R. F. Astrop, Crichton's Store, Virginia.
 Charles Meriwether, Cobham, Virginia.
 Dr. William N. Patton, Lewisburg, Virginia.
 David Turner, Richmond, Virginia.
 Dr. A. M. Grinnan, Madison, Virginia.
 Professor G. R. Rosseter, Buffalo, Virginia.
 L. C. Breckenstein, Middlesex, Virginia.
 Jed. Hotchkiss, Bridgewater, Virginia.
 J. W. Marvin, Winchester, Virginia.
 N. B. Webster, Portsmouth, Virginia.
 Marshall McDonald, Romney, Virginia.
 Professor James Phillips, Chapel Hill, North Carolina.
 Rev. J. A. Shepherd, L. Scuppernon, North Carolina.
 Rev. Fred. Fitzgerald, Jackson, North Carolina.
 H. W. Ravenel, St. John's, Berkely, South Carolina.
 Thornton Carpenter, Camden, South Carolina.
 Richard T. Gibson, Whitemarsh Island, Georgia.
 Dr. George F. Cooper, Perry, Georgia.
 Dr. E. M. Pendleton, Sparta, Georgia.
 Dr. John F. Posey, Savannah, Georgia.
 P. C. Pendleton, Powellton, Georgia.
 Professor J. E. Willet, Penfield, Georgia.
 John Darby, Culloden, Georgia.
 S. J. Cumming, Monroeville, Alabama.
 Alexander Winchell, Eutaw, Alabama.
 Dr. T. C. Osborne, Erie, Alabama.
 John Newton, Knox Hill, Florida.
 John Pearson, U. S. N., Pensacola, Florida.
 Judge Aug. Steele, Atseena Otee, Florida.
 W. S. Bogart, Tallahassee, Florida.
 A. L. Hatch, Vicksburg, Mississippi.
 Thomas Oakley, Jackson, Mississippi.
 Dr. E. H. Barton, New Orleans, Louisiana.
 J. H. Browne, Huntsville, Texas.
 President T. C. Ervendberg, New Wied, Texas.
 Dr. Samuel K. Jennings, Austin, Texas.
 Professor A. P. Stewart, Lebanon, Tennessee.
 Professor W. M. Stewart, Clarksville, Tennessee.
 Reuben Harris, U. S. N., Memphis, Tennessee.
 Professor O. W. Morris, Knoxville, Tennessee.
 Thomas L. Sawyer, Dixon's Springs, Tennessee.
 John E. Younglove, Bowling Green, Kentucky.
 Lawrence Young, Springdale, Kentucky.
 F. C. Herrick, Bowling Green, Kentucky.
 L. Berthoud, Maysville, Kentucky.
 Professor G. N. Allen, Oberlin, Ohio.
 Dr. E. C. Bidwell, Keene, Ohio.
 George L. Crookham, Jackson, Ohio.
 S. N. Sanford, Granville, Ohio.
 Edward Wade, Cleveland, Ohio.
 Rev. J. D. McMathews, Hillsborough, Ohio.
 Theo. G. Wormley, Columbus, Ohio.
 F. A. Benton, Mansfield, Ohio.
 Professor J. W. Andrews, Marietta, Ohio.
 Thomas F. Withrow, Homer, Ohio.
 L. Groneweg, Germantown, Ohio.
 Professor J. R. W. Sloane, Northwood, Ohio.
 Rev. George Duffield, Detroit, Michigan.
 Dr. W. M. Campbell, Battle Creek, Michigan.
 Thomas Whelpley, Monroe, Michigan.
 Dr. H. R. Schetterley, Howell and Ann Arbor, Michigan.
 Charles Betts, Burr Oak, Michigan.
 Elmore Wainright, Clinton, Michigan.
 L. Woodruff, Ann Arbor, Michigan.
 Dr. M. K. Taylor, Brooklyn, Michigan.
 W. W. Austin, Richmond, Indiana.
 John Chappellsmith, New Harmony, Indiana.
 Prof. J. Tingley, Greencastle, Indiana.
 Prof. P. P. Brown, Upper Alton, Illinois.
 Dr. S. B. Mead, Hancock, Illinois.
 Prof. Joel Hall, Athens, Illinois.
 Dr. J. O. Harris, Ottawa, Illinois.
 Dr. J. B. N. Klinger, Plymouth, Illinois.

T. S. Parvin, Muscatine, Iowa.
 Ida E. Ball, Keokuk, Iowa.
 Daniel McCready, Fort Madison, Iowa.
 Dr. Asa Horr, Dubuque, Iowa.
 J. A. Lapham, Milwaukee, Wisconsin.
 Rev. John Gridley, Kenosha, Wisconsin.
 Orrin Densmore, Emerald Grove, Wisconsin.
 Prof. S. P. Lathrop, Beloit, Wisconsin.
 Dr. B. F. Mills, Baraboo, Wisconsin.
 James C. Brayton, Aztalan, Wisconsin.
 Thomas Gay, Belle Fontaine, Wisconsin.
 C. F. Pomeroy, Green Lake, Wisconsin.
 Prof. J. L. Pickard, Platteville, Wisconsin.

William Ayres, Watertown, Wisconsin.
 Edward Spencer, Summit, Wisconsin.
 Samuel Spates, Sandy Lake, Minnesota Territory.
 Charles Cavileer, Pembina, Minnesota Territory.
 Alonzo Barnard, Cass Lake, Minnesota Territory.
 Rev. Stephen R. Riggs, Lac-qui-Parle, Minnesota Territory.
 Prof. A. G. Moffatt, Armstrong Acad'y, Indian Territories.
 George A. Atkinson, Oregon City, Oregon.
 Capt. J. H. Lefroy, Toronto, Canada W., British Possessions.
 Dr. Chas. Smallwood, St. Martin's, C. W., British Possessions.
 Henry Poole, Pictou, Nova Scotia, British Possessions.
 Capt. Alexander, R. E., Bermuda, West Indies.

LIST OF PERSONS FROM WHOM HAVE BEEN RECEIVED REGISTERS OF PERIODICAL PHENOMENA OBSERVED
 DURING THE YEAR 1852.

J. D. Parker, Steuben, Maine.
 Dr. Joseph L. Stevens, Castine, Maine.
 S. N. Bell, Manchester, New Hampshire.
 Robert C. Mack, Londonderry, New Hampshire.
 William Bacon, Richmond, Massachusetts.
 Henry Rice, New Attleboro', Massachusetts.
 Prof. John Johnston, Middletown, Connecticut.
 W. E. Guest, Ogdensburg, New York.
 Dr. Joseph Bates, Lebanon Springs, New York.
 John F. Jenkins, North Salem, New York.
 Cornelius Chase, Chatham, Columbia county, New York.
 John Bratt, West Point, New York.
 L. L. Fairchild, Constableville, New York.
 John Bowman, Baldwinsville, New York.
 E. N. Byram, Sag Harbor, New York.
 W. C. Belcher, Plattsburg, New York.
 Rev. Prof. A. Frost, Burlington, New Jersey.
 W. A. Whitehead, Newark, New Jersey.
 J. R. Lowrie, Hollidaysburg, Pennsylvania.
 David Peelor, Indiana, Pennsylvania.
 Prof. T. C. Porter, Mercersburg, Pennsylvania.
 John Jackson, Darby, Pennsylvania.
 Dr. R. P. Stevens, Ceres, Pennsylvania.
 Prof. J. H. Coffin, Easton, Pennsylvania.

Prof. M. Jacobs, Gettysburg, Pennsylvania.
 John Evans, Radnor, Pennsylvania.
 Dr. George Smith, Upper Darby, Pennsylvania.
 J. S. Keller, Orwigsburg, Pennsylvania.
 Prof. L. D. Williams, Meadville, Pennsylvania.
 John C. Heyser, Hagerstown, Maryland.
 Miss Harriet M. Baer, Sykesville, Maryland.
 Jedediah Hotchkiss, Mossy Creek, Virginia.
 N. B. Webster, Portsmouth, Virginia.
 R. F. Astrop, Genito, Virginia.
 Dr. John R. Purdie, Smithfield, Virginia.
 Dr. A. G. Grinnan, Madison C. H., Virginia.
 Dr. J. A. Young, Camden, South Carolina.
 Alexander Winchell, Eutaw, Alabama.
 Benjamin F. Holly, Weokaville, Alabama.
 T. C. Ervendberg, New Wied, Texas.
 John Lea, Cincinnati, Ohio.
 Robert Shields, Belle Centre, Ohio.
 L. Groneweg, Germantown, Ohio.
 Miss P. D. Childs, Keene, Ohio.
 L. Woodruff, Ann Arbor, Michigan.
 Dr. Dennis Cooley, Washington, Macomb county, Michigan.
 Prof. John M. Ordway, Trenton, Grundy county, Missouri.
 Daniel McCready, Fort Madison, Iowa.

LIST OF PERSONS AND STATIONS FURNISHING METEOROLOGICAL OBSERVATIONS TO THE REGENTS OF THE
 UNIVERSITY OF THE STATE OF NEW YORK.

J. L. Peet, Deaf and Dumb Institute, New York.
 Dr. Horace Webster, Free Academy, New York.
 Rev. Dr. Strong, Erasmus Hall, Flatbush, Long Island.
 F. H. Wines, East Hampton, Long Island.
 Professor T. Cook, Albany.
 John D. Watkins, Liberty, Sullivan county.
 M. G. McKoon, Delhi, Delaware county.
 Charles G. Hazeltine, Cherry Valley.
 J. O. Stratton, Oxford, Chenango county.
 Professor O. Root, Hamilton College, Clinton.
 Judge E. C. Reed, Homer, Cortland county.
 F. B. Downes, Ithaca, Tompkins county.
 Dr. M. M. Bagg, Utica.

Daniel Gillet, Elmira.
 W. C. Kenyon, Alfred Academy, Alleghany county.
 E. A. Dickinson, Jamestown.
 M. H. Christian, Fredonia.
 Charles Winne, Buffalo.
 Rev. Dr. C. Dewey, Rochester.
 Rev. B. Hale, Geneva College, Ontario county.
 Lyman W. Conkey, Syracuse.
 W. H. Gillespie, Mexico, Oswego county.
 Joseph W. Faylor, Plattsburg.
 J. F. Jenkins, Salem Centre.
 W. E. Guest, Ogdensburg.
 Hon. Nathaniel Jones, Newburg.

LIST OF PERSONS AND STATIONS OF THE METEOROLOGICAL SYSTEM OF THE STATE OF MASSACHUSETTS.

Prof. E. S. Snell, Amherst College.
 Prof. Albert Hopkins, Williams College.
 Henry Rice, North Attleboro'.
 Richard Edwards, Bridgewater.
 Rev. David Rowe, Westfield.
 Dr. C. H. Perkins, Newburyport.

Joshua Davis, Truro.
 Hon. William Mitchell, Nantucket.
 Dr. Edward Smith, Worcester.
 Hon. John Brooks, Princeton.
 Moses Waite, Bernardston.
 W. H. Tyler, Pittsfield.

METEOROLOGICAL RETURNS FROM THE FOLLOWING ARMY POSTS, RECEIVED AT THE OFFICE OF THE SURGEON GENERAL UNITED STATES ARMY, FOR THE USE OF WHICH I AM INDEBTED TO THOMAS LAWSON, M. D., SURGEON GENERAL UNITED STATES ARMY.

Watervleit Arsenal.
 Fort Ontario.
 Fort Constitution.
 Fort Mifflin.
 Madison Barracks.
 Fort Preble.
 Fort Sullivan.
 Fort Columbus.
 Fort Hamilton.
 Allegheny Arsenal.
 West Point.
 Fort Trumbull.
 Fort Niagara.
 Fort Adams.
 Carlisle Barracks.
 Plattsburg Barracks.
 Fort McHenry.
 Fort Monroe.
 Fort Moultrie.
 Detroit.
 Fort Mackinaw.
 Fort Howard.
 Fort Gratiot.
 Fort Gaines.
 Newport Barracks.

Mount Vernon Arsenal.
 Oglethorpe Barracks.
 Key West.
 Fort Scott.
 St. Louis.
 Fort Leavenworth.
 Fort Kearney.
 Fort Martin Scott.
 Fort Gates.
 Fort McIntosh.
 San Antonio.
 Fort Croghan.
 Fort Washita.
 San Diego.
 Fort Smith.
 Jefferson Barracks.
 Fort Brady.
 Fort Lincoln.
 Fort Duncan.
 Ringgold Barracks.
 Fort Brown.
 Fort Towson.
 Fort Gibson.
 New Orleans.

By collating these journals in the manner indicated above, the results, you will perceive, are in the highest degree interesting to science, and through science, very important to the mariner and the farmer, and indeed to all classes of mankind.

4. Though much remains to be done yet to perfect the science, by a long-continued series of wide-spread, simultaneous observations, and a careful collation of those observations, enough is already known to enable a mariner in one of our ports to know by a sudden rise of the barometer considerably above the mean, and the setting in of the wind from the eastward, that a storm is about to come on in from 24 to 36 hours, and so he will be admonished not to leave the port while these symptoms continue. The *generalizations* given below are the same which were given in the three previous reports, without any essential changes, and they may now safely be taken as a part of demonstrated science.

5. I think it cannot be doubted, the generalizations given below could hardly have been eliminated by pursuing any plan, in collating the phenomena of storms, but the one here adopted.

6. By casting your eye on one of the charts, you will see how easy it is to comprehend all the principal phases of a storm at once; the *position* and *extent* of a storm at a particular moment by the red figures indicating the quantity of rain or snow that fall in it; the *locality* of the *minimum* barometer, indicated by a red line, and its *maximum* by a black line; the *direction* and *force* of the wind, by arrows of different lengths; then by turning to the map of the next day, the *change* of position of the storm will also be seen, and *how far* it has moved towards the east.

7. It is by examining these charts* with care, and their number now amounts to upwards of eighteen hundred, printed and unprinted, and also the comparative fluctuations of the barometer laid down in curves, for every day of the whole period of my investigations, that I have been enabled to eliminate the following:

[8.] GENERALIZATIONS.

1. The rain and snow storms, and even the moderate rains and snows, travel from the west towards the east in the United States, during the months of November, December, January, February, and March, which are the only months to which these generalizations apply.

2. The storms are accompanied with a depression of the barometer near the central line of the storm, and a rise of the barometer in the front and rear.

3. This central line of minimum pressure is generally of great length from north to south, and moves side foremost towards the east.

4. This line is sometimes nearly straight, but generally curved, and most frequently with its convex side towards the east.

5. The velocity of this line is such that it travels from the Mississippi to the Connecticut river in about twenty-four hours, and from the Connecticut to St. John, Newfoundland, in nearly the same time, or about thirty-six miles an hour.

6. When the barometer falls suddenly in the western part of New England, it rises at the same time in the valley of the Mississippi, and also at St. John, Newfoundland.

* More than eleven hundred of these charts have been formed—one for each day for more than three years—for my second and third report, and more than seven hundred for my fourth report; but it would be very expensive to print them all.

7. In great storms the wind, for several hundred miles on both sides of the line of minimum pressure, blows towards that line directly or obliquely.

8. The force of the wind is in proportion to the suddenness and greatness of the depression of the barometer.

9. In all great and sudden depressions of the barometer there is much rain or snow; and in all sudden great rains or snows there is a great depression of the barometer near the centre of the storm, and rise beyond its borders.

10. Many storms are of great and unknown length from north to south, reaching beyond our observers on the Gulf of Mexico and on the northern lakes, while their east and west diameter is comparatively small. The storms, therefore, move side foremost.

11. Most storms commence in the "far west," beyond our most western observers; but some commence in the United States.

12. When a storm commences in the United States, the line of minimum pressure does not come from the "far west," but commences with the storm, and travels with it towards the eastward.

13. There is generally a lull of wind at the line of minimum pressure, and sometimes a calm.

14. When this line of minimum pressure passes an observer towards the east, the wind generally soon changes to the west, and the barometer begins to rise.

15. There is generally but little wind near the line of maximum pressure, and on each side of that line the winds are irregular, but tend outwards from that line.

16. The fluctuations of the barometer are generally greater in the northern than in the southern parts of the United States.

17. The fluctuations of the barometer are generally greater in the eastern than in the western parts of the United States.

18. In the northern parts of the United States the wind generally in great storms sets in from the north of east, and terminates from the north of west.

19. In the southern parts of the United States the wind generally sets in from the south of east, and terminates from the south of west.

20. During the passage of storms the wind generally changes from the eastward to the westward by the south, especially in the southern parts of the United States.

21. The northern part of the storm generally travels more rapidly towards the east than the southern part.

22. During the high barometer on the day preceding the storm it is generally clear and mild in temperature, especially if very cold weather preceded.

23. The temperature generally falls suddenly on the passage of the centre of great storms, so that sometimes when a storm is in the middle of the United States the lowest temperature of the month will be in the west on the same day that the highest temperature is in the east.

Query.—Does the southern boundary of these winter storms reach the belt of high barometer in the northern border of the trade winds? and does the northern border of these storms reach into and beyond the belt of low barometer near the arctic circle?

Do these storms commence at the Rocky mountains? and do they traverse the entire Atlantic with similar phenomena to those contained in the above generalizations? In what direction exactly do they move? Is it not towards a point of the compass a little south of east?

That the above twenty-three generalizations, which are the same as in the previous reports, with slight modifications, will be proved to be true laws of nature, by a more copious induction of facts, I have but little doubt; and my confidence is founded chiefly on the three following reasons:

9. *First.* On the known uniformity of nature in the production of phenomena. From this uniformity it is highly probable, nay, almost certain, that if a certain set of phenomena are observed to accompany all the storms investigated, even if the number is few, and they are now more than one hundred, these same phenomena will be found to accompany all storms; and such is the fact, so far as investigations have yet gone, as it relates to the fundamental generalizations given above.

Second. I ground my belief, that these generalizations are the true laws of nature, on the fact that all the phenomena yet observed connected with storms are explained by the following

[10.] THEORY.

When the air in any locality acquires a higher temperature or a higher dew-point than that of surrounding regions, it is specifically lighter, and will ascend; in ascending, it comes under less pressure and expands; in expanding from diminished pressure, it grows colder about a degree and a quarter for every hundred yards of ascent; in cooling as low as the dew-point, (which it will do when it rises as many hundred yards as the dew-point at the time is below the temperature of the air in degrees of Fahrenheit,) it will begin to condense its vapor into cloud; in condensing its vapor into water or cloud, it will evolve its latent caloric; this evolution of latent caloric will prevent the air from cooling so fast in its further ascent, as it did in ascending below the base of the cloud now forming; the current of air, however, will continue to ascend, and grow colder about half as much as it would do if it had no vapor in it to condense; and when it has risen high enough to have condensed, by the cold of expansion from diminished pressure, one hundredth of its weight of vapor, it will be about forty-eight degrees less cold than it would have been if it had had no vapor to condense, nor latent caloric to give out—that is, it will be about forty-eight degrees warmer than the surrounding air at the same height; it will, therefore, (without making any allowance for the higher dew-point of the ascending current,) be about one-tenth lighter than the surrounding colder air, and, of course, it will continue to ascend to the top of the atmosphere, spreading out in all directions above as it ascends, overlapping the air in all the surrounding regions in the vicinity of the storm, and thus, by increasing the weight of the air around, cause the barometer to *rise* on the outside of the storm, and *fall* still more under the storm cloud, by the outspreading of air above; thus leaving less ponderable matter near the centre of the upmoving column to press on the barometer below.

11. The barometer thus standing below the mean under the cloud in the central regions, and above the mean on the outside of the cloud, the air will blow on all sides *from without, inwards*, under the cloud*. The air on coming under the cloud, being subjected to less pressure, will

* Besides the fluctuations of the barometer depending on storms, as explained in the text, there are four daily fluctuations produced entirely by the increasing and diminishing elasticity of the air, due to increasing and diminishing temperature.

When the sun rises, the air begins to expand by heat; this expansion of the air, especially of that near the surface of the earth, lifts the strata of air above, which produces a reaction, causing the barometer to rise; and the greatest rise of the barometer takes place when the increase of heat in the lower parts of the atmosphere is the most rapid—that is, about 9 or 10 a. m. The barometer from that time begins to fall; and at the moment of maximum heat, when the air is neither expanding nor contracting, the barometer indicates the exact weight of the atmosphere. The barometer, however, continues

ascend and carry up the vapor it contains with it, and as it ascends will become colder by expansion from constantly diminishing pressure, and will begin to condense its vapor into cloud at the height indicated before, and thus the process of cloud-forming will go on.

12. Now, it is known that the upper current of air in the United States moves constantly, from a known cause, towards the eastward, probably a little to the south of east;* and as the up-moving column containing the cloud is chiefly in this upper current of air, it follows that the storm-cloud must move in the *same direction*. And over whatever region the storm-cloud appears, to that region will the wind blow below; thus the wind must set in with a storm from some *eastern direction*, and, as the storm cloud passes on towards the eastward, the wind must change to some *western direction*, and blow from that quarter till the end of the storm. These are the elements of the theory of storms, which, with the numerical results, are demonstrated proximately in my work on the Philosophy of Storms.

13. The fundamental principles of this theory, so far as I know, have never been disputed by any philosopher. It is true Professor Peirce, of Harvard University, has attempted to show that I attribute *too much* power to the evolution of latent caloric in the formation of cloud when the dew point is low; but his calculation is vitiated by two fundamental errors, which, when corrected, will leave the result of my calculation untouched.

First. Professor Peirce assumes it as a principle that as the air ascends it will expand precisely as much as the pressure is diminished; that is, if one-tenth of the pressure is removed by going up to a certain height, it will expand into one-tenth greater bulk, and if one-half the pressure is removed, it will expand into double the bulk, &c., without making any allowance

to descend, on account of the diminishing tension of the air and consequent sinking upon itself, as the evening advances, and its greatest depression is at the moment of the most rapid acceleration of diminution of temperature, which is about 4 or 5 p. m. At this moment the barometer indicates a less pressure than the true weight of the atmosphere. The whole upper parts of the atmosphere have now acquired a momentum downwards, which, as the motion diminishes, causes the barometer to rise above the mean; this takes place at the moment when the diminution of the motion downwards is the most rapid. This maximum of rise, which takes place about 10 p. m., is small, when compared with that at 9 or 10 a. m. As the barometer now stands above the mean, it must necessarily descend to a mean at the moment when the air is neither increasing nor diminishing in temperature, which is just before sunrise. If this is the true explanation of the four daily fluctuations of the barometer, it will follow that the morning rise ought to be greater at considerable elevations on mountains, provided they are not too great, because some of the air will be lifted above the place of observation by the expansion below. And this deduction agrees well with the observations of Colonel Sykes in India: he found the nocturnal falling minimum fluctuation from 10 or 11 p. m. to 4 or 5 a. m. to be .0181 inch at Poona, about 1,800 or 2,000 feet high, and the diurnal rising fluctuation from 4 or 5 a. m. to 9 or 10 a. m. to be .0445 inch; and at the height of 4,500 feet he gives these same fluctuations, .0240 and .0636 inch; and at the height of 6,407 feet, .0433, and .0490, as observed by Dr. Walker and M. Dalmahoy.—[Royal Phil. Trans. for 1835, page 196.] At very great elevations, it is probable that there would be only two fluctuations in a day—the maximum near the time of the greatest heat, and the minimum near the time of the greatest cold of the air. At moderate elevations, such as four or five thousand feet, the effect is to prolong the morning maximum at the upper station, so that it continues to rise *there* for some time after it has begun to descend at the lower station. Observations are wanting to determine this last deduction of theory.

[Since writing the above, I have seen Captain Wilkes' observations on a mountain in one of the Sandwich islands, upwards of 13,000 feet high, where, from his tables, it appears that the barometer had but two fluctuations in the twenty-four hours—the minimum early in the morning, and the maximum towards 3 o'clock in the evening; and this was the only point in my theory which needed confirmation when the theory was proposed.]

The principle here assigned as a *vera causa* is too plain to admit of doubt. It is the mere application of the law that "action and reaction are equal and in opposite directions." It may, however, be illustrated in the following manner: Let a person balance himself in a pair of large scales in a stooping position. If he raises himself, his scale descends; and when he is erect, equilibrium is restored. In stooping down, his scale ascends as soon as his downward motion commences; and when his velocity downwards begins to diminish, his scale descends below equilibrium; and when he comes to rest, equilibrium is again restored: thus four oscillations of the scales will be produced by one upward and one downward motion of his body, corresponding to one expansion and one contraction of the air in a day by heat and cold.

* See 182.

for the diminution of bulk produced by the cold of expansion, which amounts to an important quantity at great elevations.

Second. The Professor assumes it as a principle that, if air is cooled one degree by an expansion from diminished pressure of one hundred and forty-second part of its bulk, as it is, then an expansion into double the volume will cool it one hundred and forty-two degrees, &c. Now, though the *exact* law of cooling for different expansions and different temperatures was not known when these calculations were made, yet it was well ascertained that the rarer the air and the colder, the less is the cold produced by a given expansion.

The number of degrees of cold actually produced in the ascending air is not near so great at great elevations as the law assumed by Professor Peirce would make it, as will be shown more fully hereafter.—(See No. 141.)

14. The theory, then, is impregnable on scientific principles, and if it should ever be refuted, it will only be by a long course of observations on storms themselves, exhibiting phenomena altogether different from those which have heretofore been observed on this continent, which now amount to near two hundred.

15. I am aware that Redfield, Reid, Piddington, and Thom, who have all examined the phenomena of tropical hurricanes with much care and labor, have come to the conclusion that these hurricanes are *round*, and are exhibited in the form of great whirlwinds, in which the centrifugal force, by withdrawing air from the central parts of the storm, causes the barometer to fall there, and, by bringing down the cold air of the upper regions, and mingling it with the warm air below, produces cloud. But neither of these theoretical deductions can be correct, for it is acknowledged by them that the air blows inwards spirally, and of course upwards in the middle. Besides, even if it blew outwards below from the centrifugal force, and came downwards in the middle, no cloud could be formed by this downward motion, for it is demonstrated by experiment that the further it descends the more vapor it will be able to contain; so that even if it was saturated above when it descends so far as to occupy only one-half the space by increased pressure, it will then be capable of containing more than four times the quantity of vapor which it contained above, in consequence of its increased heat by greater pressure.

Again, if it shall be determined that the air in some storms in the tropical regions or elsewhere blows inwards, not directly, but spirally, there is no way of accounting for a fall of the barometer in the central regions but by supposing some cause for the air's running outwards above faster than it runs inwards below, while the barometer continues to fall. This cause cannot be a centrifugal force above, because the upper parts of great storm-clouds exhibit no such phenomena. Besides, no other cause than the evolution of latent caloric can be admitted, even in part, for the fall of the barometer under the cloud, because this alone, as is shown in my philosophy of storms, is adequate to the effect, whether the air moves directly or spirally inwards below. Besides, if there is a whirl in any storms, as there probably is in some tornadoes, it can only be explained by the centripetal force due to the fall of the barometer from the cause which I have assigned; that is, the evolution of latent caloric by the continual condensation of the vapor which goes up with the ascending air, and then only in storms nearly round. When the temperature and dew point are very high, and the up-moving column of air is very narrow, the violence of the motion upwards may be so great as to carry large drops of water formed in the cloud far up into the region of perpetual congelation, where they freeze, and, not

being permitted to fall back through the ascending column, are *thrown outwards at the sides, as the cloud moves along, in the form of two veins of hail*, having imbedded in the hail-stones all kinds of materials taken up from the surface of the earth by the ascending current.

In the case of a very high dew point—that is, when there is a very great quantity of vapor in the air—it is manifest, from the great quantity of latent caloric evolved in the formation of the cloud, that the top of the cloud will be at a great height from the surface of the earth,* because all the vapor will not be condensed until it has attained a great elevation; therefore, the barometer will continue to sink lower and lower while the cloud is increasing in perpendicular diameter; and as the barometer sinks lower and lower, the up-moving column will form clouds lower and lower than its original base, from the expansion and cold due to the diminished pressure on it when it comes in under the base of the cloud; and for every inch that the barometer falls cloud will begin to fall about four hundred yards lower down, or nearer to the surface of the earth, right under the centre of the cloud, where the barometer stands lowest.

16. Thus, if the dew point is eight degrees below the temperature of the air, and, of course, the base of the cloud eight hundred yards high when it first begins to form, when the cloud has increased so much that the barometer under its centre has fallen one inch, the air will expand so much on coming in under the base of the cloud, from the diminished pressure there, that it will begin to condense its vapor on going up four hundred yards, and the appearance of the cloud will now be that of an udder or great protuberance sticking down from the centre of its original base; and when the up-moving column with its cloud has become so lofty, and given out so much latent caloric in condensing its vapor, that the barometer has fallen two inches, then the air which comes in under the cloud, when it reaches the centre, will expand, from diminished pressure, enough to cause, by the cold of expansion, cloud to form at the very surface of the earth. This is the manner in which, according to the theory, a tornado or water-spout is formed; and it agrees well with the descriptions of their formation given by those who have observed them from their beginning.† The violence of the wind rushing towards the apex of the

* See No. 66.

† The mode in which nature operates, as I conceive, in the formation of storms, and especially tornadoes, may be illustrated in the following manner:

Imagine a cylindrical vessel ten miles wide at its base, which is closed and high enough to reach to the top of the atmosphere, its base being elevated above the surface of the earth, say about nine hundred yards, that is about the height at which we may suppose the base of a forming cloud to be. Now, if this vessel is supposed to be filled with air of the same temperature and dew-point as the air on the outside of the vessel all the way from the base of the vessel to the top, it is manifest that the barometer would stand at equal altitudes in the inside of the vessel and on the outside on the same horizontal level. Suppose, now, that the air in the inside of the vessel is heated $44^{\circ}.8$ above its former temperature, which we will suppose to be at a mean zero of Fahrenheit, it will then expand into one-tenth greater bulk, and one-tenth of the whole will run over the top of the vessel, and spread itself out on the top of the atmosphere.

If this heat were suddenly communicated to the air, the air would expand suddenly, and at the moment of the expansion a barometer in the inside of the vessel in any part, but more especially near the base, would rise, and stand considerably higher, until the air should much of it run out at the top, but when it had all run out that would by its increased bulk, the barometer would stand one-tenth of the whole, lower on the inside of the vessel at the base than on the outside at the same horizontal level; that is, if we suppose the barometer on the outside of the base to be 28 inches, the barometer on the inside of the vessel at the base would stand 2.8 inches below 28 inches.

If now a small hole is bored in the bottom of the vessel the air will run in with a velocity due to the superior head of pressure on the outside of about 2,700 feet of air of the density of the air at the base of the vessel, that is, with a velocity per second of $\sqrt{2,700 \times 8} = 415$ feet.

* A well known formula for falling bodies or spouting fluid.

If the air entering through this small aperture should acquire on entering the temperature of the air within, the barometer in the inside would experience from the influx but little rise, because the air at the top and throughout the

cone of cloud now reaching the earth will be very great, and where the tornado passes through a forest the manner in which the trees are thrown down will demonstrate the direction of the wind. The trees at the sides of the path of the tornado, as it moves in this latitude towards the east, or a little north of east, will be thrown inwards towards the centre of the path, and

whole length of the vessel would have but little motion upwards, and the reaction would hardly be appreciable; but if the whole bottom should be taken out of the vessel, the air would not flow in and up the vessel with near the same velocity as that of the streamlet entering through the small aperture, and the barometer would rise considerably in the inside of the vessel at the base, and fall on the outside of the vessel near the base, and this fall would be extended to a considerable distance from the base of the vessel, even down to the surface of the earth, diminishing in quantity as the distance from the open mouth of the base increased, and this, too, on supposition that the air entering the cylindrical vessel constantly acquired the same temperature above that of the air on the outside which it had before. The reason why the barometer in the inside of the vessel would rise after the bottom should be taken out is, that the air in rushing up the vessel would constantly increase in velocity as it diminished in density from diminished pressure, and this increase of velocity would react on the air below, and thus keep the barometer constantly higher than it would stand, from the simple weight of the air at rest, and this would be the case in every part of the vessel from its base to its top; and even at the very top, where the barometer had no height before the base was taken out, would now rise a little, in consequence of there being a column of air forced up over it. The air thus pushed up over the top of the vessel will roll outwards in all directions around, and by increasing the quantity of air all around the top of the vessel, it will cause the barometer to rise a little at the surface of the earth all around the vessel, at the same time that it sinks under the vessel. The greatest depression of the barometer under the vessel will be under the middle of the base, that is, in the axis of the cylinder prolonged, and therefore the air will press inwards on all sides towards that axis, to rush into the open base of the vessel containing the lighter air.

If the air which comes in on all sides to go up in the cylinder has a dew point of 64° , that is, has an elastic force of vapor equal to 0.600 inches, then it will have to ascend to where the barometer stands about $5\frac{1}{2}$ inches high before it will have condensed all its vapor by the cold of expansion from diminished pressure, and in condensing it will give out latent caloric sufficient to heat the whole column at a mean about $44^{\circ}.8$; for at the upper part of the cloud, and from that to the top of the vessel, it will be 60° warmer than it would be if it had gone up without any vapor in it to condense.—(See 143.)

I find it difficult to calculate precisely how much the barometer would rise in the inside of the cylinder near the base on taking out the bottom and letting the air run in freely below, but at whatever height the barometer might stand while the air was thus admitted below to pass up and out at the top of the atmosphere, it is very certain that if the upper half of the cylinder were removed the barometer would fall very considerably in consequence of the spreading out on all sides of a portion of the air, which previously had been compelled to preserve its cylindrical form to the top of the atmosphere, reacting all the way up on the barometer below, by its constant expansion and acceleration in velocity. Besides, the swelling up of the air above the mean level of the atmosphere would be greater before the upper half was removed than after, and on this account the barometer would stand higher on the inside with the longest cylinder. If the cylinder should be made still shorter, by cutting it in two again and removing the upper half, the barometer would fall still lower, for the same reasons as were assigned before.

Again, the barometer would fall still more if the cylinder, now only one-fourth the length it was at first, should be widened out from its base to its top in the form of a truncated cone, with its base upward, increasing in size upwards just as much as the air itself in moving upwards increases in volume by diminished pressure. In this latter case the column, to a great height, of up-moving air would be in the shape of an inverted cone, gradually assuming a trumpet shape, higher still from the more lateral motion of the air, with its apex on the ground, and if the whole vessel were now removed the same shape would nearly be retained, and there would be but little change in the motion of the air or the height of the barometer.

It will also be manifest, by a little consideration, that the only place where the air all around this ascending cone of air can get in to the axis of the cone is at or near the surface of the earth, for the air which ascends from there will prevent the air all the way up from approaching the axis by its elasticity and continual expansion from diminished pressure in its upward motion. On the outside, therefore, of the ascending cone of air, at a few hundred yards above the surface of the earth, there will be but little motion of the air towards the axis of the cone, and therefore but little fall of the barometer except near the axis of the ascending air. From this view of the subject, it appears manifest that, though the column of heated air does not commence at the surface of the earth, but nine hundred yards above it, yet the barometer will sink nearly as much at the apex of the cone of up-moving air at the surface of the earth, below the height it has there on the outside of the ascending column, as it does in the centre of the ascending column nine hundred yards high, where the heated column commences, and reaches from there to the top of the atmosphere.*

The air, then, in the ascending cone will be supplied almost entirely by the air which enters at its apex near the surface of the earth; and at considerable heights, so far from the air running in towards the axis of the cone from without, the air, by its natural expansion from diminished pressure, would, at the moment of taking away the upper part of the cylindrical vessel, in which the air was confined, as imagined before, spread outwards, and thus cause the barometer to rise a little, as its first effect on the outside of the ascending column; but after the up-moving air had spread itself out into the

* In the tornado where the inverted cone of cloud reaches down to the surface of the earth the heated column reaches the earth also.

those in the centre will be thrown either right backwards, contrary to the motion of the tornado, or right forwards, according as some of them will be thrown down by the front part of the meteor, where the wind blows backwards, or by the rear, where the wind blows forwards; and as those which are thrown down by the front of the tornado must fall first, they, of course, will

form of a cone with its base upwards, and the air on the outside of the ascending column remained at rest, the barometer in the still air, however near it might be to the air in motion, would not be affected at all by the ascending column.

From the consideration, then, that the ascending column of air in a cloud, heated by the latent caloric just evolved, is free to expand outwards from the axis as well as upwards, its reaction downwards is much less than it would be if moved up in a hollow cylinder, and of course the barometer will sink much lower at the apex of the cone than under the base of the cylinder, though not quite so low as in the cylinder with its base closed, as before calculated, it being understood that in both cases there is the same difference of temperature between the air in the upmoving column of air and the air on the outside of that column.

It is not difficult, then, to conceive the sudden and violent explosive force that is manifested when the apex of the cone of the tornado comes over a house, diminishing the pressure on the outside of it to the amount of more than a pound on each square inch, permitting the air within to throw up the roof, and burst open bureaus, and explode the corks of empty bottles in cellars, while the bottles full of wine are not disturbed. Again, if we suppose that sometimes a whirl takes place in the very centre of the tornado, the explosive force will be much increased, though the uplifting force will then not be so great. And if, besides all this, we suppose that sometimes a flood of electricity rushes down through the centre of the tornado, where the great rarefaction and condensed vapor may be supposed to furnish a better conductor than dense and transparent air, causing each particle of air to repel its neighbor, and thus producing a degree of rarefaction in the air far beyond that which is caused by the evolution of the latent caloric of the condensing vapor alone, we have a power let loose of which it is difficult to calculate the force.

It is quite probable that both electricity and a whirl sometimes are present in a tornado, for tornadoes are sometimes described as presenting a pillar of fire and smoke, and it is quite natural that the inblowing of the air below should sometimes produce a whirl. I once thought that all tornadoes whirled, and was only compelled to abandon this idea by an examination of the manner in which trees are prostrated in the paths of tornadoes.

There is one phenomenon which it would seem easier to explain on the supposition of the presence of electricity, and that is the concentration of the action of the tornado to a narrow space for a long time. It would seem that if all the power of the tornado depended on the latent caloric of the condensing vapor in the cloud, the rapid expansion of the cloud above would soon increase the width of the upmoving column, and change the tornado into a widespread rain, in which case there must be a calm in the middle. At present, I must leave this question undecided until the very shape of the upmoving column is calculated, for which proximate data are given below.

1. The mean temperature of a column of air from the surface of the earth to the top of the atmosphere. [Given in No. 141, 142.]
2. The temperature of the air in its normal state at any assumed height above the surface of the earth. [121, 122, 142.]
3. The degree of cold produced by any given expansion of dry air in ascending columns. [141, 142.]
4. The degree of cold produced by any given expansion of moist air with a known dew-point in ascending columns. [143.]
5. The whole quantity of vapor that can be condensed by the cold of expansion from diminished pressure in upmoving columns of air. [64.]
6. The specific gravity of the cloud, and the whole upmoving column, when compared to that of surrounding air, which may be deduced from known data in connexion with those given here; hence a general formula for the specific gravity of any cloud with a given dew-point, and temperature of the air below may be investigated, and the dynamics of the air thus brought under the dominion of mathematics.

The problem is commended to the notice of the profound analysts.

When the dew-point is very high, and the lower air contains more caloric for a given weight than the upper, whether a tornado will be formed or not from the upmoving current, which will certainly take place in these circumstances, will depend on the size of the column, which moves up. If the column is very wide at its base, that is, even a few miles wide, then a tornado cannot be formed, it may be a hail storm, which always approaches to the character of a tornado; for though the air, in coming in under the cloud, does not reach the axis of the upmoving column before it begins to ascend, yet the upward motion is so great in the cloud itself as to carry the drops of water up to a great height, where they freeze, or at least freeze when thrown out at the sides of the upmoving inverted cone, in air much colder than the air in the cloud, and in falling down on the outside, are not unfrequently carried into the upmoving current by the inrushing of the air below, and then carried up again to be thrown out above, surrounded with a new layer of water, to be frozen again in its descent through the cold air on the outside, and this process is probably sometimes repeated several times, as hail stones are sometimes found with four or five distinct layers of ice and snow. Indeed, it is probable that as hail storms have a motion along the surface of the earth, all the hail stones that are thrown out above in front of the storm are caught up on their descent by the advancing storm and carried aloft again, as it is known that in the most violent hail storms the hail only falls at the two sides of the cloud as it moves along, sometimes falling in two parallel veins, fifteen or twenty miles apart and several hundred miles long.—(*Philosophy of Storms*, page 20 of Introduction.)

be found, where there is any overlapping, under those which fall forwards. Now, these were found to be the phenomena in the Brunswick tornado, by Professors Bache, Henry, Johnson, and myself, who all examined this tornado with great care soon after its occurrence; yet Mr. Redfield thinks he finds unequivocal proofs of a whirl in this very tornado in a direction contrary to the hands of a watch laid on its back, while Colonel Reid asserts that all the water-spouts which he has seen whirl in the opposite direction.

Having myself examined the Brunswick tornado with great care, I agree with Bache, Henry, and Johnson, that the phenomena prove a direct inward motion of the air towards the centre, and upwards in the middle. Besides, I examined the phenomena several miles east of the place where the tornado disappeared, and ascertained from many eye-witnesses that an immense number of shingles and boards fell that same afternoon, *along with a heavy shower of hail*. These shingles must have chiefly been taken up from the houses in the city of New Brunswick, more than twenty miles west of where many of them fell. I did not learn from any of the witnesses that any of the shingles were covered with a coating of ice; but Judge Brown, of Nashville, Tennessee, informs me that branches of trees are known to have fallen on the passage of a tornado in that region, covered with a thick coating of ice, along with a heavy shower of hail.

Soon after the investigation of the New Brunswick tornado by Henry, Johnson, Bache, and myself, I made a tour through New Jersey, New York, and Pennsylvania to visit the localities of tornadoes the ravages of which might in part be still visible. I found nine such, and they all exhibited the same phenomena as to the direction in which the trees were prostrated, all being inwards at the sides, and forwards in the middle. The only exception to this uniform regularity was, that in the New Brunswick spout three patches were found, nearly circular, with the tops of the trees all thrown inwards from the circumference towards one common centre. In the middle of one of these stood a large house, which had its roof carried off, and the trees all round the house had their tops thrown towards the house.

So far as I know, the New Brunswick spout or tornado is the first ever investigated in such a manner as to discover and announce any regularity in the manner in which the wind must have blown at the surface of the earth; and I hope I may be permitted to record the fact as a true historian, that all three of the gentlemen named above had been made acquainted with my theory of storms and tornadoes before they commenced the examination of the phenomena of this tornado, and all came away from the examination with the conviction that the trees were thrown down as I had predicted from my theory they ought to be.

The examination of this tornado was soon followed by the examination of others as they occurred from time to time.

First, Professor Loomis, then of Ohio, following the example of Professor Bache, gave a chart of the position of bodies thrown down by the great tornado of the morning before day of the 20th October, 1837, and the direction in which the trees were thrown down. He says, in Silliman's Journal: "It will appear from an inspection of the diagram that in the midst of some disorder there was a degree of uniformity. Thus, upon either border of the track, the trees all incline towards some point in the centre of the track. There is not an example of a tree being turned outward from the track, nor even one which lies parallel to it. I except from this remark those near the middle of the path. * * * This is a striking result, and clearly shows that the wind blew from both borders of the track towards some point

in the centre of the track. This remark does not apply to one part of the track exclusively, but was the general characteristic of the hurricane. * * * * We are now in a situation, I think, to explain nearly all the phenomena which have been observed. The wind blew from the opposite sides of the track, and doubtless from every point of the compass, towards some point in the centre of the track; here the wind rose violently in a gyral motion. This vortex itself had a rapid motion from west to east, sweeping along over the middle of the hurricane's path. Trees, then, upon the borders of the track would everywhere fall towards the vortex. Those which were prostrated as the vortex was approaching would have an inclination to the west; but those which fell as the vortex was receding would be found inclined towards the east, and we should nowhere find trees falling outward from the track, or even parallel to it, except in the centre of the path." All this is in exact conformity with the observations.

Next comes, in Silliman's Journal, also, an account of a violent tornado which occurred near New Haven, on the 31st July, 1839, by Professor Olmstead, of Yale College. The professor gives a chart of the direction in which the trees were thrown down, following also the example of Professor Bache, he says: "The first great fact that strikes us is, that all the trees and other objects that mark the direction of the wind which prostrated them are, with very few exceptions, turned inwards, on both sides, towards the centre of the track; while near the centre the direction of the prostrate bodies is coincident with that of the storm. The length of the tornado did not exceed four miles, and its average breadth was only sixty rods, varying, however, a little in different places. Its duration at any one place did not exceed half a minute, and its progressive motion may be estimated at forty miles per hour. It came suddenly, with torrents of water; there was a rush, a crash, and it was gone.

"Numerous examples are seen where the bodies as they fell towards the centre of the track, or after they had fallen, were turned further round towards the direction in which the tornado was moving, that is, towards the northeast."

Next comes the tremendous tornado of Natchez, on the 7th of May, 1840. Professor Forshay, of Natchez, in a letter to Drs. Dodge and Warder, published in the Cincinnati Gazette, says: "Everything seems to have corroborated Mr. Espy's 'Philosophy of Storms,' and everything to militate against every other explanation of such violent atmospheric commotion. In the first place the oppressive heat of the forenoon, and particularly just before the storm. * * * * Second. The roaring sound of the wind, veering from east to southwest gradually as the tornado was passing, keeping constantly towards the centre of the track. Third. The extreme depression of the barometer while the storm was raging, and the *explosion* outwards of nearly every room and building in the city. Very often, perhaps in one hundred cases, the gables of houses both blew out, even in the very teeth of a wind raging at several hundred feet per second! Close hatches were blown open upwards, and a desk, containing only one and a half cubic feet of air to each apartment, burst the locks off its three doors. Fourth. Trees were *pulled up* by the roots and carried several yards, and then fell without breaking their limbs; and this happened with the largest trees. Men were picked up and carried to a distance and let down without violence or injury. On the margins of the storm, the limbs and leaves of trees fell in great numbers, and the tin from the roofs of buildings was found twenty miles hence, and a piece of steamboat window was recognized thirty miles northeast of Natchez. Fifth. The position of trees was demonstration complete, in the absence of other evidence. The nearer the axis of the tornado,

the nearer were their bearings parallel with that axis; and the more remote, the nearer perpendicular; while those that point to the direction from which the storm came, or cross a line perpendicular to the axis, *lie beneath* those that point in the forward direction of the same."

In another letter to a friend Professor Forshay says: "I have done nothing since the storm but examine its track and collect information, and, while I have seen thousands of corroborations of his theory, I have sought in vain for things it could not account for. The whole city of Natchez is blown towards the track I have specified; while the bearings of trees and houses falling more westerly are invariably superimposed by those that fell more eastwardly."

Next comes the great tornado of Châtenay, near Paris, France, which occurred on the 18th of June, 1839. M. Peltier gives an account of this spout. M. Peltier, who thinks electricity is the cause of all the phenomena attending tornadoes, nowhere says that the wind blew inwards towards the centre of the tornado as it passed; yet he mentions several facts from which it may be inferred that such was the case. He says: "The trees which bordered this avenue were to the east of the spout, which advanced from the south to the north. On the west side of these trees—that is to say, on the side next the passage of the spout, all the leaves were dried and scorched on their borders, while the leaves on the opposite, towards the east, had preserved their freshness and verdure. All these trees were inclined to the west, a little north; instead of being straight, they were bent towards the place of the passage of the spout." (Peltier sur Trombés, page 142.) "Two hundred and fifty metres further on there were fruit trees on the border of its path; these trees had on the west-northwest, like the first, all their leaves dried and scorched, whilst the leaves on the east-southeast were preserved fresh. These trees were not merely inclined, but entirely prostrated, and lying on the ground turned to the west-northwest"—[that is, towards the passage of the spout.]

"In following the march of the meteor and the line of trees thrown down, it appeared evident that the destruction of the houses of this street was not caused by the direct passage of the spout, but by the lateral influence; for the trees of the orchard of M. Herelle indicated that the column passed between this orchard and the street of Mareil. All the fruit trees of this orchard were thrown down towards the north-northwest, whilst those of the road of Fontenay to Fosses, which was parallel to it at about twenty-five metres, were thrown towards the north-northeast. From this place the spout deviated again a little to the east, entered the park of the castle, and devastated it in the most disastrous manner. All the trees of the high forest were torn down; three quarters of them had their trunks dried and split into small splinters, or in the form of a broom. The centre of the park had its trees overturned in a most singular manner, and an apple-tree was carried two hundred metres and placed on a pile of oaks and elms; but this confusion only existed in the centre. All the trees in the periphery had been thrown down with their tops towards the centre of the park, as M. Lalanne has shown in the plan which he made."—(Peltier sur Trombés.)

Next comes the tornado of the 22d of August, 1851, near Cambridge, Massachusetts, a part of which was carefully examined by the Rev. Charles Brooks, and another part by Professor Henry L. Eustis.

Mr. Brooks says: "The state of the atmosphere from sunrise to the time of the tornado was peculiar. Many spoke of a dead closeness, a remarkable want of elasticity in the air. Coming from Waltham, the central line of march seemed to be from W.S.W. to E.N.E., till it reached

the western edge of Medford. Here it changed its direction slightly, and moved from W. by S. to E. by N., keeping this line to the edge of Malden, beyond which I have not traced it. I use the word centre to designate that *line of march* towards which objects on both sides were thrown. Measuring from the outer southern and northern edges, where marks of violence were unequivocally left, I found the width to vary considerably. At Mystic river its width was seventy-one rods; at the Lowell R. R. depot, sixty rods; at Miss Brooks' it was fifty rods; * * * and at Fulton street probably not much more than forty rods.

"In several places the distance from the centre to the outer southern edge is from eighteen to twenty-five rods further than from the centre to the northern edge. At one place the ravages on each side were nearly equi-distant from the centre. Another fact connected with the subject of width is this: that it seemed to dart off on each side, at unusual distances, and do violence in a narrow-pathed excursion, or rather (to speak more intelligibly) there seemed to be some strata of air on its outer borders, more ready to rush in towards the central line of march than contiguous strata. * * * This rush of wind in veins, from the outer edges to the centre, is marked over the whole route." [It would be worth while to inquire if large quantities of rain or hail fell in patches on the borders of this tornado as it passed, which would increase the violence of the wind inwards towards the centre of the track, and thus account for the rush of wind in veins from the outer edges to the centre.]

"I would state, *as a general fact*, that there was uniformity in the direction in which objects were thrown down. * * * With respect to trees, those which were standing in the centre of the line of march, supposing that centre to be a line running W. by S. and E. by N., lie coincident with that line. Those which were nearest to this line on each side of it lie nearly parallel with it, but not exactly. Those on the north side of the centre point to spaces between the E. by N. and E., while those on the south side of the centre point to spaces between E. by N. and E.N.E. Those on the north side, which are further yet from the centre and next to those last mentioned, point to spaces between E. and E.S.E., while the corresponding ones, on the south side, point to spaces between E.N.E. and N.E. Those which are further still from the centre on the north side lie pointing to spaces between E.S.E. and S.E. by S.; while those in corresponding distances on the south side lie pointing to spaces between N.E. and N. by E. Those on the north side, which are furthest from the centre, lie pointing inwards at right angles to the central line of march, and so of those on the south side; of course the trees on the two margins of the track lie with their tops pointing exactly towards each other. Nine-tenths of the trees prostrated by the tornado lie in the positions above designated. Those which are not directly upon the central line lie pointing to that line. This is true of the trees and shrubs and corn and grass up to 90° distant from the point E. by N. on each side, and there, at 90° from that point, they stop—all being included within E. by N. and S. by E. on one side, and within E. by N. and N. by W. on the other!

"The above statements record the general facts respecting the directions in which trees and other vegetables were thrown by the tornado. It seems to us as if a vacuum had travelled (if we can so say) fifteen or twenty miles from W. by S. to E. by N., and the wind had rushed in with violence, not only behind it but on each side, towards its central line of motion, prostrating the trees in the manner above stated." [If the Rev. Mr. Brooks had said, "it seemed as if the wind rushed from all points of the compass towards a vacuum in the tornado, with less

violence from the E. by N. than from other points," the remaining tenth of the trees would nearly cease to be anomalous; for those trees which, near the central line, are thrown backwards, are under those which are thrown forwards, whenever there is one tree lying on another.] For instance, Mr. Brooks says: "In Mr. Swan's field four large elms standing in a row, running east and west, about twenty feet apart, were all prostrated, the most easterly towards the N. by W.; the next one west of it towards the E. N. E., with its body *upon* the roots of the other; the one next west fell towards the east and lies over the lowest part of the trunk of the most easterly one. The last most westerly elm fell pointing towards the east. Here we have four large elms, which stood in a row running east and west, all prostrated; the one furthest from the place whence the tornado came falls towards the N. by W.; while the other three lie upon it and fell, one to the E. N. E., the other two to the east.

"In Mrs. Porter's lot, ten rods north of centre, lies a large cedar pointing west; covering the roots of this lie two cedars pointing S. E. by S.

"As to a whirl," says Mr. Brooks, "I find but one tree twisted by the wind, and that is a large cedar, five and three quarter rods south of centre, and it lies pointing N. N. E. The twist is from the south towards the east, and from the east towards the north, just half a revolution. Near by lies a very large cedar pointing N. E. by E. It fell across a wall, as the other did, and its trunk is split lengthwise for several feet into twenty or thirty layers; but it is not twisted in the least. Throughout the track in Medford I find no evidence of a rotary motion in the force which prostrated the buildings, trees, &c. There may have been a swift and constant motion round a perpendicular centre, but this revolving whirlwind did not blow down the trees and corn. If it had done so, the trees and corn would have lain in curves and circles corresponding to the direction of the force; whereas they all lie straight.

"The ground and grass were definitely marked in extensive open fields, and no sign of curvilinear motion could be detected. All showed straight lines of march towards the central line. On the central line, where the apex of the inverted cone just touched the earth, there we should expect to find trees twisted off, but I find not one. Large trees, which were broken off from five to ten feet from the ground, exhibit uniform testimony. The sap-wood on the west side did not break so readily as the interior layers, and therefore it was peeled off in strings; these strings remain erect as they stood, and show not a trace of twist.

"Having no theory to patronize or decry, I readily accede to the testimony in this particular."

Mr. Brooks gives no chart of his investigations; but Mr. Eustis has given the exact position of every prostrated tree in another part of the tornado of 18,000 feet in length, in a map, on the scale of one hundred feet to the inch. He says: "A mere glance at the map will show that throughout the whole track the trees generally point inwards towards the axis, so that at almost any point a person may put his finger on the axis line.

"This dip towards the axis is most satisfactorily explained, not by considering the trees as thrown down by the direct force of the wind, but rather by regarding the storm as a mass moving with great velocity along its well defined axis, overthrowing everything in its way, and leaving behind it a vacuum, towards which everything on the borders of its path collapsed."

[I would suggest to Professor Eustis that the storm cannot be considered as a solid mass, and therefore there is nothing in its nature to hinder the air from collapsing towards the vacuum from the front as well as at the sides and in the rear; and if so, it will account for the fact of

some trees in the centre of the path being thrown backwards, and also why those trees are found underneath those that are thrown forwards; whereas if they fell backwards by reaction, as Mr. Eustis thinks, then they would be found on top of those thrown forwards, as they never or seldom are.]

“As to the theory which maintains that each tree is twisted from its bed as one might be supposed to extract a screw, I feel bound to say that, though a most faithful search was made for evidence, yet, throughout the whole extent of these observations, only two cases have been met with which can be twisted to agree with the theory. A tall hickory was found standing, and twisted 180° upon its own trunk. The top rested upon the ground. The other case is that of a chimney on the left or northwest side of the axis. The bottom of this chimney stood firmly, while the top was twisted round upon it as if it had been a distinct block, *the south side of it moving towards the west.*

“Though many broken trees were examined, some of them broken entirely through the trunk, others only as far as the heart, no evidences of torsion were found; the fractured fibres were everywhere straight.

“A very significant fact in its bearing upon this point is the following: The course of the tornado was from southwest to northeast. It held in suspension a great quantity of muddy water, and we find, as we examine the houses, and trees, and stone walls which it met in its course, that the southwest face of these is spattered with mud, while the northeast face remains clean. In some of the trees which I examined, it is no exaggeration to say that the line of demarcation between these two surfaces was as well defined as if one face had been painted with a mud-wash, and the other left in a natural state.”

In examining the map of the tornado by Professor Eustis, I find a locality south of the centre, on which it is recorded, “the southern side of these trees and wall covered with mud.”

I would respectfully suggest to Mr. Eustis and to the reader, that as there is no mention of mud being on the north side of trees that were on the north side of the centre of the track, though the wind certainly blew from the north on that side, whether there were some wet grounds or ponds on the south side, or whether it might not have rained on the south and rear of the spout, and not on the north side, at the moment of the passage of the meteor? I know not how to account for the phenomenon in question on any other supposition; and yet no rain is mentioned by either Mr. Brooks or Mr. Eustis. Perhaps it is not yet too late to ascertain the fact. The inverted cone of cloud certainly contained moisture and dust—moisture from the condensed vapor, as was explained at the beginning of this article, and dust taken up by the ascending current of air; but I do not see how this could account for the mud being on the south side of the trees on the south side of the track, and not on the north side of the trees on the north side of the track. If it should be admitted that the wind blew inwards on all sides of the inverted cone, where there was a partial vacuum, nearly all the anomalies will disappear. In this case, the wind in front of the tornado would blow backwards, and thus account for all the trees thrown backwards being thrown down first; and, of course, those which are thrown down by the rear of the tornado will lie on top. And if it shall be found that large masses of rain or hail fell at a few hundred yards from the outside borders of the storm, it will explain how a tree may be thrown down in the midst of a forest, while the trees all round it may be undisturbed—a phenomenon not before mentioned, which Mr. Brooks says occurred to “a large

old apple tree, seventy-four and a half rods S.S.E. of what seemed to be the outer southern edge of the tornado. This tree was beheaded, split, and lies pointing exactly east. A hundred trees in its immediate vicinity were equally exposed, yet remain untouched."

In the American Journal of Science, vol. 17, page 290, an account of a tornado is given, which occurred in Knox county, Ohio, on the 20th of January, 1854, about 3 P.M. Its course was northeast by east through its entire length of about ten miles. In its course it entered a piece of woods half a mile long, and cut a swath through it of the uniform width of a quarter of a mile. The appearance of the prostrate woods is very curious. In the centre of the storm-track the trees are laid in parallel lines. Toward the outer edge on each side they gradually diverge from the parallel till at last they lie quite at right angles to the line of the storm. Along the edges of the path the trees are not at all injured. It occupied from two to five minutes, according to different estimates, in passing any one point. It seems to have worn the appearance of a mighty, black pillar, reaching from earth to heaven, irradiated by blinding flashes of lightning, and accompanied in its devastating march by the music of a hundred cannon.

The effect of an upmoving column of air in a small way may be shown by causing a vacuum of between two and three inches of mercury in the upper end of a perpendicular tube a few feet long and five inches in diameter, by attaching it to the central opening of a fan blower in rapid motion. In such an arrangement the air will rush into the mouth of the tube below with a velocity proportionate to the square root of the diminished pressure in the tube, about 240 feet per second for a diminished pressure of one inch of mercury. In such an arrangement it will be found that when a basin of water is brought under the mouth of the tube, and placed within two and a half inches from the mouth, the water will be drawn up from the basin rapidly and carried off up the tube, thus imitating a miniature waterspout. When the tube is of glass of the same dimensions, the column of water is seen to spread out above in the form of an inverted cone of spray as it ascends.

This experiment was made at a foundry in the city of Washington, in the spring of 1852, before Professor Henry and several distinguished members of Congress.

THUNDER STORMS.

To the Editor of the New York Tribune:

SIR: A great deal has been written about storms—much from theoretical deductions, and some from fact. My purpose in this treatise is to relate the physical aspect of thunder storms as viewed from above the clouds from the surface of the earth, from their sides in mid-air, and from the middle of their cauldrons. I have made diligent observations on these meteors for ten years past, and have read some theories concerning them; but as my object is mainly to give facts to the student of meteorology, I will confine my relation at present to that which developed itself to the sense of seeing, hearing, feeling, and smelling of these phenomena.

A storm viewed from above the clouds has the appearance of ebullition. The upper surface of the cloud is bulged upward and outward, and has the resemblance of a vast sea of snow boiling and upheaving from internal convulsion. The view is from a point where the atmosphere is clear around and above. Immediately above the storm the air is not so cold as in a place where there is no cloud nor storm beneath. The falling of the rain can be heard above the cloud,

making a noise like a waterfall over a precipice. The thunder heard above the cloud is not loud, and the flashes of lightning appear like streaks of intensely white fire on a surface of white vapor.

A side view of a storm, observed when it is a mile or two off, and somewhat lower than the point of observation, presents in form the shape of an hour-glass; the picture of a waterspout also gives a good outline of its shape. In this well defined form it moves along over the earth. When the storm is so small that you can embrace its whole bulk at a single glance—which you can do when you are several miles off, and a little more elevated than the meteor—it looks as though it were trailing its lower base along on the surface of the earth, and it has an individuality which cannot be recognized when viewed from the ground. Although the storm is being moved along by the same current of wind that is drifting along the observer, it will be deflected from that course by its encountering a mountain ridge, or a deep valley, just in proportion to the amount of lateral force or obstruction it sustains in such cases; and then the observer in a balloon may continue onward, while the storm may be moving off at right angles with his route. These lateral views of storms are very grand and imposing as they rush along by an elevated observer. A grand army of flying artillery at full gallop, in all the panoply of war, could not produce so imposing a sight; over city, forest, river, and plain it goes with undaunted march.

A closer view from the side of a storm, and partly in it, reveals a very interesting physical aspect. The one now described occurred on the 3d of June, 1852, during a balloon excursion from Portsmouth, Ohio. The storm was kedging up the Ohio river, about fifty miles above Portsmouth, and where the river courses nearly north and south, while I was sailing from west and east. Moving at nearly right angles with the storm soon brought us together, and the country below being dense forest, the meteor's company was preferred to a reception in the woods. It was easy to keep out of the vortex of the storm from an abundant supply of ballast aboard of the air-ship, hence a point in its wake was the station of observing its action; and having learned that the shape of storms was like two cones with their ends joined, with a wind driving in below and rushing out again at its top, you might sail with impunity in its wake, provided you kept midway between the upper and lower cloud. When getting too low in its wake, there was a tendency to rock the balloon into the vortex, but this was counterbalanced by going up near the outspreading cloud. In this position the air is cold, and you are in the shadow of the upper cloud, unless you sink low enough where the sun may reach you under the overlapping cloud. Although the sun was shining on me, the rain and small hail were rattling on the balloon. A rainbow was standing in and against the body of the meteor, or rather a prismatically colored arch the shape of a horse-shoe was reflected against it, and as the point of observation changed laterally and perpendicularly, the perspective of this golden grotto changed its hues and forms. Above and behind this arch there was going on the most terrific thunder, but no zig-zag lightning was perceptible, only bright flashes like explosions of "Roman candles" in fireworks. Occasionally there would be a zig-zag explosion in the cloud immediately below, and the thunder therefrom sounded like a "*feu de joie*" of a rifle corps. Once an orange-colored wave of light seemed to fall from the upper to the lower cloud, and right over the balloon, but no sensible effect was produced by its contact. This was "still lightning." There appeared all the time while in the storm electrical action going on in the balloon, such as expansion, tremulous tension, attraction by lifting papers out of the car ten feet below the balloon, and hugging them to its body for a moment and then letting them drop off again; but

as I had no instruments, I can only relate the manifestations of electricity in this case. While, as stated above, a distant view of storms is imposing and grand, a closer view of a great storm, such as this Ohio meteor, is truly sublime, although the rushing noise below and in its midst, like the tumult of a thousand chariots of war, is almost appalling.

The quantity and quality of thunder seem to be in proportion to the magnitude of the storm. A storm may be so limited in size as that there will be no electrical explosions. In this case the developed electricity can be dissipated and taken up by the immediately surrounding cloud formation. April and May showers are an exemplification of this fact. When the storm is of great magnitude, the central portion of its top becomes surcharged with electricity, because the surrounding cloud-formed vapor cannot conduct away silently as fast as it is developed, and hence explosions must ensue, such as noticed in the Ohio meteor, with terrific and rapid discharges of thunder; and, moreover, the drops of rain that are formed from this surcharged vapor of the upper cloud also becomes redundantly electrified, and although they fall quietly down through the intervening clear air, which is a non-conductor, as soon as they reach the lower cloud, which is negatively electrified, they give up their surplus, silently if the capacity of this cloud is sufficient to take it up, but explosively if the cloud is insufficient; and it may fly off laterally until dissipated, or it may glance downward to the earth, rending whatever it encounters before its diffusion in the earth. The physical facts here stated are as I saw them; the rationale of explosion is confirmed from the known play of electricity as divulged by the common electrical machine experiments.

A storm viewed from within its cauldron—that is, from within its vortex, where the cloud vapor is driving upward to where it spreads out—is rather a terrible thing; and the very fact that you are caught up in the midst of one of nature's laboratory furnaces makes you feel resigned, and determined to look to the end thereof. It may be only terrible because we are not used to it; nevertheless, I would not like to enter one again for observation until science dictates, without a doubt, that we are not liable to annihilation or serious harm. The one now to be described is the result of a trip in the midst of a local storm of so limited dimensions as to have no electrical explosions during my passage of nineteen minutes within its bosom. This storm originated nearly over the town of Carlisle, Pennsylvania, on the 17th of June, 1843. I entered it just as it was forming. The nucleus cloud above was just spreading out as I entered the vortex unsuspectingly. I was hurled into it so quick that I had no opportunity of viewing its surroundings outside, and must, therefore, confine this relation to its internal action. On entering it the motion of the air swung the balloon to and fro, as also around in a circle, and a dismal, howling noise accompanied this unpleasant and sickening motion; and in a few minutes thereafter was heard the falling of heavy rain below, resembling in sound a cataract. The color of the cloud, internally, was of a milky hue, somewhat like a dense body of steam in the open air, and the cold was so sharp that my beard became bushy with hoar-frost. As there were no electrical explosions in this storm during my incarceration, it might have been borne comfortably enough but for the sea-sickness occasioned by the agitated air-storm. Still, I could hear and see, and even smell, everything close by and around. Little pellets of snow (with an icy nucleus when broken) were pattering profusely around me in promiscuous and confused disorder, and slight blasts of wind seemed occasionally to penetrate this cloud laterally, notwithstanding there was an upmoving column of wind all the while. This upmoving stream would carry the

balloon up to a point in the upper cloud, where its force was expended by the outspreading of its vapor, whence the balloon would be thrown outward, fall down some distance, then be drawn into the vortex, again to be carried upward to perform the same revolution, until I had gone through the cold furnace seven or eight times, and all this time the smell of sulphur, or what is now termed ozone, was perceptible, and I was sweating profusely from some cause unknown to me, unless it was from undue excitement. The last time of descent in this cloud brought the balloon through its base, where, instead of the pellets of snow, there was encountered a drenching rain, with which I came down into a clear field, and the storm passed on. This storm may have been accompanied with electrical discharges after it left me, as it had the appearance of increase as it departed. I may here mention, that the people in the neighborhood informed me next day that it deposited two parallel trains of hail some distance apart. I have frequently since and before this occurrence witnessed storms while up in the air, but a great distance off, sometimes four and five of them at the same time in different parts of the heavens, and always in the months of May and June, and never accompanied with electrical explosions when they were small in dimensions.

Thunder storms, viewed from the earth, have not the characteristic shapes lineated to the eye of the observer as when viewed sidewise from above; neither does one discover the two plates of clouds joined in conic sections. The upper cloud can be seen rolling outward, and black clouds below centering inward, but the whole seems to be nearly blended in one solid mass. By close observation and practice it will soon be deduced that there are two plates of clouds, even as viewed from the earth. In watching clouds carefully from the earth, it will be observed that vivid zigzag flashes and heavy peals are followed by copious showers. The rain drops, being positively charged from the upper cloud, drop through a clear atmosphere, which is a non-conductor, into the lower cloud, which is negatively electrified; and if the shower is too copious for the lower cloud's capacity to absorb it silently explosions must follow, in the same way as the Leyden jar explodes spontaneously when surcharged to overflowing. Were it not for the lower cloud and its negative condition the surcharged drops of rain would scintillate their electrical fire as they touched the earth.

Thunder storms rage more violently as they pass over forests and moist places, and were it not for the deposition of rain as they pass along their track would exhibit a parched trail. A long drought is adverse to the generation of a thunder storm, and on the other hand a moist earth is promotive of one.

Thunder storms are deflected from their courses, as well as retarded in their movement, by friction on the earth. Ascending from the earth with a balloon in the rear of a storm, and mounting up a thousand feet above it, the balloon will soon override the storm, and may descend in advance of it. I have experienced this several times.

I have thus related facts which are due to science, with a view to a more accurate understanding of the laws which govern them; and in order to spread them broadcast before the investigating minds of the day in this department of science, I forward you this account, to be published in your wide-spreading journal should it meet your approbation to do so.

JOHN WISE.

LANCASTER, PA., *February*, 1857.

It has been supposed that the different velocities with which the earth moves on the north and south side of hurricanes and tornadoes will cause a whirl from the north round by the west in the northern hemisphere, and from the south round by the west in the southern hemisphere.

Let us suppose a hurricane in the West Indies reaching from latitude 14° to latitude 16° , blowing at a mean 70 miles an hour. Now the diurnal motion of the different latitudes is as the cosine of the latitudes, and the cosine of the latitude 15° is 18.7 miles greater than that of latitude 16° , and less than that of 14° , and if twice 18.7 be multiplied by 3.1416, it will give 117.5, the number of miles which the surface of the earth moves in a day further at latitude 15° than at latitude 16° ; this number 117.5 being divided by 24, will give 4.9, the distance which the surface of the earth moves per hour greater at latitude 15° than at latitude 16° . Now as the wind which blows towards the centre of the hurricane is supposed to move with at least the velocity of 70 miles an hour, it will come from latitude 16° to latitude 15° in an hour, and therefore, without making any allowance for spiral motion, its eccentricity will be only four miles and nine-tenths, but as the winds, which come in on the east and on the west side of the hurricane, will have no tendency to whirl, the amount of deviation from the centre must be diminished one-half.

If we suppose the hurricane to be only one-half this diameter, and some are not more, and are generally more violent in proportion to the smallness of their diameter, then the eccentricity of the motion of the air would be only one-quarter of this, that is, 0.61 miles.

But as a large portion of the air goes up from the surface of the earth before it comes as near the centre as this, leaving a central calm, the whirl, when the dimensions of the hurricane are small, will hardly be perceived.

This will appear more distinctly when we consider tornadoes, which we now proceed to do.

Suppose a tornado half a mile wide; at latitude 15° the cosine for a quarter of a mile is 422.4 feet greater than that of a quarter of a mile lower latitude, and the double of this 844.8 multiplied 3.1416 to turn it into revolution, makes 2,654, which is the number of feet that the surface of the earth, at the southern border of the tornado, would travel in a day further than the centre. If, now, we suppose the velocity of the wind to be such that it will pass from the borders to the centre, one-quarter of a mile, in six seconds, and if we divide 1,654 feet by 1,440, the number of minutes in a day, it will give 1.84 feet, and this would be the eccentricity if it took one minute for the air to go from the borders of the tornado to the centre; but as we have supposed it took only six seconds, or one-tenth of a minute, this number 1.84 feet must be divided again by 10, which gives 0.184 foot, or 2.208 inches, for the eccentricity. And if we suppose the tornado to be only half this diameter, then the eccentricity would be only one-fourth of this number, or 0.552 inches.

If we suppose a tornado to be at $34^{\circ} 30'$, with the same dimensions, its eccentricity would be just double the above; that is, in the first case 4.416 inches, and in the second case 1.104 inches.

From these calculations it is manifest that no whirl can take place in tornadoes from the causes in question. Let us see whether any whirl can be formed in hurricanes. It has been said "That the gyrations below approach the centre in a spiral, but this approach must be slow towards the centre; for at a certain distance from the centre the gyrations become so rapid that the centrifugal force nearly equals the centripetal produced by the external pressure of the atmosphere, and then the further approach towards the centre in a great measure ceases, and

consequently, the force that produces the gyrations. Hence, at a certain distance from the centre, the hurricane has the greatest violence, and within this circumference friction, in a great measure, destroys the gyrations, so that the middle of our most violent hurricanes is a calm. The extent of this calm is a circle varying from five to thirty miles in diameter."

The reasoning of this paragraph is plausible, but not sound, with the exception of the last clause.

The calm is not produced by the whirl resisting the inward motion of the air by its centrifugal force, but by its upward motion before it reaches the centre. There is a large space in the centre of all hurricanes, where the barometer stands nearly at the same point, and towards this space the air rushes from all sides, and begins to ascend as soon as it comes under a pressure less than a mean. If it did not do so, the storm-cloud could not be formed; and if the central calm is from five to thirty miles in diameter, all the air rises several miles before it comes to the place where it would be as near the centre as it would come if it should pass straight, without going in a spiral at all.

If it was not so, but whirled round before going up, so as to balance the inward motion by centrifugal force, it would stop the air from coming in, and so the hurricane would terminate; it is only by going upwards, and leaving a free entrance to the air behind, that the force is kept up.

It has been said, that "It is only on the principle of gyration that the rapid motion of the air in the hurricane can be produced, and any theory which does not take this principle into account is defective."

Now, so far from this principle rendering the velocity of the air greater, it is manifest that the velocity is just the same at equal distances from the centre, whether the air whirls or not, leaving friction out of the question; and with friction, the air that goes the most direct will move the fastest.

There is another phenomenon attending hurricanes, which is altogether incompatible with *rapid* gyrations near the centre—it is the gradual dying away of the wind as the centre approaches. If the air gyrated, it ought to increase in velocity up to the very edge of the calm; but such is not the fact, as will be seen by the account given by Mr. Thom of a hurricane which passed over the island of Mauritius on the 10th April, 1840, page 109:

"About 9 A. M. the severity of the storm began to subside to irregular blasts and calms. By 10 A. M. it was a light wind, and in half an hour quite calm. It seemed as if the storm was over; the sky became lighter, the sun broke out about noon, and it was so fine that we walked through the village to survey the scene of devastation. Still the barometer continued low, and cumulous clouds were drifting rapidly across the sky from the N. N. W., opposite to the direction whence the gale had ceased blowing. At 2 P. M. a dark, lowering, well-defined, unbroken bank of clouds was seen approaching from the northeast. It was like a canopy drawing over the mountain in the interior, and we could see that rain was poured out from it. Its motion towards us was by no means rapid, and in no comparison with that of the clouds flying over our head. In half an hour after a few squalls warned us of its proximity, and it again burst over the place with a fury that baffles description."

The calm space in this hurricane was at least 21 miles in diameter, as observations were made at Port Lewis and at Souillac, 21 miles apart, and the calm extended from one to the other, and

lasted at each place about four hours. The barometer was stationary at one place at its lowest the whole time of the calm, and at the other it rose 0.05 of an inch. Now, one of two things is certain in this hurricane—either the centrifugal force of the wind was not the cause of the calm, or, if it was, the wind would have been prevented from blowing inwards, and so the hurricane would cease. Besides, Port Lewis is almost exactly north of Souillac, 21 miles distant, and it appears, from a journal kept at Port Lewis, that from 9½ A. M. till 2 P. M. the wind blew a hurricane from *N. N. E. to N. W., changing to N. N. W. at noon, while, during the same hours, it was calm at Souillac*; that is, the wind blew a hurricane for three or four hours exactly *towards, not at right angles to, a region of calm.*

What became of all this wind which blew with such violence for such a length of time towards Souillac without reaching it? It ascended to teach us how the cloud is made all round, and how the calm is made in the middle.

This reasoning acquires additional force from the consideration of the form of the island.

“From the representation given by M. Bailly, as quoted with apparent approbation by Darwin, it would seem that basaltic mountains form a series of ramparts, extending, with some interruptions, all round the coast, with their strata inclined towards the sea, and their escarpments facing on all sides the centre of the island.

“Within this ring of basaltic matter occur those streams of lava which have overspread so much of the interior, so that M. Bailly boldly supposes that the hollow was formed by the sinking in of the whole upper part of one great volcano.”—(Daubeny on Volcanoes, p. 434.)

The wind, then, in the tornado, or waterspout, and hurricane does blow inwards at the circumference and upwards in the middle, as it does in the great winter storms. For the manner in which the theory explains numerous other phenomena, I must refer you to my work on the Philosophy of Storms.

The third and last reason for believing that the above generalizations are the true laws of nature is, that, by means of the knowledge which the theory furnishes, under the favorable circumstances of a high dew-point and a calm atmosphere, highly beneficial rains in time of drought have been produced artificially. Since this deduction from the theory was first announced, more than seventeen years ago, a great many persons from various parts of the United States have sent me descriptions of phenomena, coming under their own observation, where clouds were formed and rain produced immediately over great fires, while it was clear all round, in such a manner that they were satisfied *the rain was produced by the fire*. I give below a few of these certificates, which, without any more, will be sufficient to satisfy you on this point:

[17] COWDERSPORT, PA., July 29, 1844.

DEAR SIR: The undersigned, citizens of Cowdersport and vicinity, desiring to render you what little aid they can, beg leave to present to you their testimonies to the following facts:

On Saturday, the 13th of July, about one o'clock, the fallow of D. H. Ellsworth, esq., containing about six acres, was fired. At the time the fire was set the day was calm and warm, and would be considered clear. There were some flying clouds, with slight appearances of rain to the north, but none in the neighborhood. The fire spread rapidly, and burned with great violence. In a short time a white cloud was seen to form over the black smoke which rose from the fire with great velocity, nearly perpendicular. The white cloud rolled outwards above,

especially towards the north and south, and probably still more towards the east, as the wind was gentle in that direction, and as the rain which fell from it increased as it proceeded east, as far as heard from. It did not swell out very far to the west. In less than an hour from the commencement of the burning very large drops of rain were seen by the inhabitants of Cowdersport descending from the cloud, glistening in the sun like diamonds. It rained but little in Cowdersport, which is about one hundred rods west of the fire, and none at all one-half of a mile west of the village. This latter fact was remarked particularly by Charles Lyman, who was ten miles west of Cowdersport at the time of the burning, and who found the road very dusty until he came within a very few rods of the village, where the first edge of the shower made its appearance. Mr. Lyman lives two miles east of Cowdersport, and he found that the quantity of rain which had fallen constantly increased as he advanced. When he got home he found the ground quite wet. Previous to the rain it was quite dry and parched, suffering much for want of rain. Samuel Taggart lives six miles east of Cowdersport, and at his place the shower was very violent, with unusually large drops of rain. The shower at Mr. Taggart's did not last, probably, more than thirty minutes, but it rained an unusual quantity for the time.

Some of our citizens watched the whole formation of the cloud, and its gradual recession towards east after the rain; and we have understood from credible authority that it rained hard and much longer the same afternoon many miles to the east. We are unanimously of opinion that *this rain was produced by the burning of the fallow*; and we think it due to your zeal in the cause of science to make this communication to you. We wish you every success in your efforts to discover the laws of nature on this important subject. We tender you our hearty thanks for your visit to Cowdersport, particularly for your kindness in explaining to us the laws which govern the formation of clouds and the progress of storms; and we give you a cordial invitation to repeat your visit next season, assured that we will render you every aid in our power to make further experiments on this highly interesting subject.

Very truly, yours, &c.,

JOHN S. MANN, *Attorney at Law*.

CHARLES LYMAN.

W. C. BUTTERWORTH, *Attorney at Law*.

SAMUEL TAGGART.

JOHN B. PRADT, *Episcopal Clergyman*.

DAVID T. HALL.

Professor ESPY.

DEAR SIR: I was not at Cowdersport when the fallow of D. H. Ellsworth was burnt, but the testimony of the most respectable citizens of this village, who address you this letter, proves, to my entire satisfaction, that *the rain was caused by the fire spoken of*. The fallow in question was the first burnt in this neighborhood this season, and was watched by many of our citizens to see the effect, and I believe there is no doubt in the minds of any that *the rain was produced by the fire*, in a way, however, they did not understand at the time of its burning.

The Rev. Mr. Pradt, our Episcopal minister, informs me that he watched the cloud which formed over the fire, and one of our innkeepers, A. H. Butterworth, did the same, the fire being about half a mile southeast of their residence, and that it was extremely black underneath, but its western boundary hardly reached the zenith, and that only a few drops of rain fell where they were, while it was pouring down violently in sight a short distance to the east.

I have also been informed by a respectable gentleman of McKean county that a fallow of considerable size had been burnt in his neighborhood on a very clear day, and that almost immediately after it was fired a cloud formed, and produced a heavy shower directly east of the fire, and none to the west of it, a fuller statement of which I will furnish you with hereafter.

Yours, respectfully,

TIMOTHY IVES, *Associate Judge.*

Soon after this rain I travelled eastwardly from Cowdersport, and found that the rain increased in quantity and duration in that direction, as the following certificates will show:

JULY 28, 1844.

I live about twenty-two miles east of Cowdersport, and about two o'clock on Saturday, the 13th of July, I left home in a beautiful clear day, but I had travelled only about three miles when a very heavy shower came on, the drops being uncommonly large, glittering in the sun much of the time. The cloud came up from the west, and had not covered the whole sky when the rain came on; indeed, it did not cover the whole sky at any time, though the rain lasted from a half to three-quarters of an hour. This was the first rain we had for a considerable time, and was very much needed.

E. JOHNSTON, *Justice of the Peace.*

I hereby certify that I am well acquainted with the subscriber, E. Johnston, and I believe the above statement over his signature to be true.

TIMOTHY IVES, *Associate Judge.*

POTTER COUNTY, PENNSYLVANIA:

Understanding that you wish to know whether it rained here on Saturday, the 13th July, 1844, I have to inform you that about three o'clock there was a very hard shower about six miles to the east of this place, twenty-eight miles east of Cowdersport, where I was at the time, and I found when I returned home that it had both rained and hailed hard the same afternoon at my house, twenty-two miles east of Cowdersport.

Yours, respectfully,

FRANCIS L. METZGAR.

Mr. ESPY.

Dr. W. Hembel Salter, of Pulaski county, Indiana, gives me an account of a rain which was produced by the burning of a prairie, seven or eight miles northeast of his residence, on the 6th day of August, 1843. He says:

“WINNIMAC, INDIANA, August 28, 1843.

“The day had been exceedingly sultry and warm; the thermometer stood at 88°; several clouds were seen floating at the time at a great height, but there was *no appearance of rain*. At fifteen minutes before three o'clock a gentle breeze sprung up from the southwest, blowing directly towards the fire, which at three o'clock had increased to a perfect gale. The dark volumes of smoke and flame at this time had ascended to a great height, when, after reaching an immense height, it was observed, by the direction which the dark mass assumed, that there was a counter current of the atmosphere above, towards the west by southwest. I was now an

eye-witness to the formation of clouds. At first the cloud was insulated; I could see all round it, and I do not believe any other clouds were seen at that time within fifty miles of this place. Nothing could exceed at this time the magnificent appearance of the sky.

"The clouds kept forming until, seemingly unable to support their weight, they rolled over each other until they appeared to have enveloped the whole heavens in gloom, when, falling into the lower current, they were conveyed towards the northeast, where, I think, much rain must have fallen. Slight showers took place at six o'clock in the evening; it commenced raining again about twelve, and continued to rain very fast until nine o'clock next morning, when it ceased. It remained cloudy the whole of this and the following day, when it cleared away.

"There was much heavy rain fell from three to eight miles west of the town, and from ten to twenty-five or thirty miles east and northeast, beyond which I have not been able to obtain information. The formation of the clouds all appeared from the course designated, and appeared to be increased after the first was well defined with astonishing rapidity. The whole of this beautiful display of nature was witnessed and would be testified to by Major Gardner, register of public lands at this place.

"Your obedient servant,

"W. HEMBEL SALTER, *M. D.*

"J. P. ESPY, Esq."

18. DEAR SIR: Your request for a relation of my experiments upon your theory of storms is flattering. I answer it with pleasure. They were at first accidental, and afterwards intentional. I will describe both.

In 1845 I was engaged in the public survey on the Atlantic coast of Florida. Some time in April (the time of the dry season there, which lasts up to June) I was running a township line between latitudes 26° and 27° , about five miles from the sea. The weather was oppressively warm that day; there was not air enough stirring to move an aspen leaf. We found our line must pass through a saw-grass pond containing about five hundred acres. In ponds of this description the green grass at the top shoots up from five to six feet in height, and when the region has not been for some years swept clear by fires, the dead and dry growths of preceding seasons accumulate under the latest growth, and are often found there from two to four feet in depth. They are exceedingly inflammable. When lighted in dry weather, they burn with frightful rapidity and violence. Whenever, in our explorations, we came upon a place of this description, we could only pass our line by cutting away the lofty fresh grass, and wading (or rather wallowing) through the mud and the under rubbish. On the day in question we determined, as it was so hot, that, to save ourselves trouble, we would burn our way through. I had then no thought of your theory. In order to prevent the flames from running over the woods, through which we were obliged to pass, we communicated them at once to both sides of the spot we desired to open, that they might converge and combine in its centre, and not scatter laterally. In a very few minutes an awful blaze swept over the entire surface which we had marked out for our purpose. We then crossed our line. Ere we had proceeded over forty chains a delightful breeze sprang up and cooled the atmosphere, and presently a refreshing shower sparkled in the bright rays of the sun. All this excited no further observation than that it had not rained before there for a long time. I myself did not observe any smoke, nor the formation of any cloud.

Our work went on for some days without a repetition of our short cut at pioneering, some objection having been made when another burning was proposed, because the first one had rendered it difficult, after crossing the lines, to distinguish the white men from the negroes. At length, however, the pleasant breezes ceased, which had made the weather for a while endurable, and the still air and intense heat returned, and with them constant murmurs from the men, especially the negroes, whose duty it was to cut lines and mark trees. We were now on the confines of a saw-grass pond, and a much more formidable one than any we had yet encountered. Being surrounded by a cypress swamp, we concluded that it had never yet been burned. My assistant, Captain Alexander Mackay, who was standing by my side, mentioned his having in our late conflagration observed the formation of a cloud at the apex of the smoke, he added that it had frequently since brought to his mind some account which he had read of Professor Espy's theory. He suggested that there could not be a better opportunity than this to put the theory to the test, and being fond of a joke, he said he would like to astonish the superstitious negroes, and to make them believe that he could call together the clouds and bring down rain. So we determined to make the experiment.

When our party were all gathered at the halting place complaints of the extreme heat went round, and all unanimously agreed that a more confined and oppressive day had never been known to them. To these complaints the usual wishes for a "little breath of air" and "a few drops of rain" succeeded. "Cut through this pond," exclaimed the captain, "and I'll bring you more than a few drops of rain; I'll give you a plentiful shower, and a breeze, too, that shall wake you up. Come, boys, cut away, and when you've done you shall wash off the dust in a cold bath from the skies!" They stared up and around; not a cloud as large as a man's hand was to be seen, and they looked back at the captain with a good-natured grin of incredulity. "Ho, ho!—ha, ha! captain make cloud out o'nuffin; he, he!—captain bring water all dis way from de sea! Ho, ho!—ha, ha!—he, he!" Whereupon the captain affected to be very indignant. To hasten his victory, I ordered the grass to be set on fire. The flames soared forthwith above the tallest trees; a dense volume of smoke mounted upward spirally; the grass soon disappeared; we crossed over. As the smoky column broke and the cloud began to form, the captain traced a large circle in the sand around him, and placed himself in its centre, making fantastic figures and forming cabalistic phrases out of broken French; still was the cloud unnoticed. All eyes were riveted upon the captain, who stood gazing at the earth, and shaping outlines of devils there. At this juncture came a roll of distant thunder; every glance instantly turned upward; a cloud was spreading there; the thunders increased; the lightnings flashed more vividly; the knees of the negroes shook together with alarm; already was the rain descending, and in torrents, though the clear sky could be seen in all directions under the cloud. The captain, meanwhile, maintained his mystical attitude, and continued his wild and extraordinary evolutions. Some of the whites who were in the secret of the hoax fell upon their knees, and were imitated by the negroes, whose fears augmenting as the storm grew fiercer, with clasped hands fastened upon the captain a stare of awe and deprecation. In short, the scene presented a more complete triumph of philosophy over ignorance than I could have supposed it possible to have been produced anywhere in the nineteenth century, and most especially anywhere in our enlightened republic.

We often fired the saw-grass marshes afterwards; and whenever there was no wind stirring

we were sure to get a shower ; and I say with perfect confidence that we never had a shower in April or May at any other time. Sometimes when there was a breeze, it would carry the smoke towards the horizon, where there would seem to be a fall of rain.

Such is the experience upon which I rest my faith in your theory ; which I should not have supposed it possible that any scientific mind could doubt, had I not heard otherwise from yourself.

I have the honor to be, dear sir, most respectfully, your very obedient, humble servant,

GEORGE MACKAY.

P. S.—I have lately been informed by A. H. Jones, United States deputy surveyor, that he has performed a great many experiments in Florida, of a similar nature, with like success ; and that for some years several farmers, who became acquainted with these experiments, have been in the habit of setting fire to the dry grass at the time they plant their corn to produce rain ; and that they generally succeed, though (this being in the dry season) it is known that no rain would otherwise occur.

G. M.

JULY 14, 1846.

DEAR SIR : Having read some of your Theory relative to storms, and knowing your general wish to obtain all correlative evidence to the proof and support of your theory, I hope you will not think me imposing upon your patience if I describe to you what came under my own immediate observation.

I have been on Isle Royale, Lake Superior, seven weeks, conducting a mining company. For the first two weeks we had frequent rains ; but during the last two weeks in May, and since that time, we have had no rain, with the exception of two days, and probably one night. For the last two weeks previous to this date, we have had neither rain nor clouds that would bring rain. On the 11th of July, the woods on the island, either accidentally or by design, took fire.

The rocks in this country are covered with a heavy growth of moss, and the trees, which are mostly spruce, Canada balsam, birch, white cedar, and white and yellow pine, are also hung with moss similar to that which is found in the south. It collects upon the underbrush, which is so thick that a man can only with great difficulty make his way through it.

The fire during the night of the 11th spread to a slight degree, but on the 12th the wind rose and the flames raged like a whirlwind, seeming to leap from tree to tree like threads of electric fluid, and darting onward as if desirous to consume every living thing. The moss, the branches of the balsam trees, the pitch concealed in the rough bark, and that still more ignitable matter, the outside bark of the birch, all seemed to woo the fiery element to the fullest display of its resistless fury.

During the burning on the 12th, there appeared clouds around and about the fire, which swept away to the east of the fire. In the evening the wind ceased, and all was clear as before, and the fire seemed smouldering as it were in repose after the destruction of the day. On the morning of the 13th the wind arose with more than usual violence about 10 o'clock. The fire had spread a mile or two to the west, and had become one general conflagration for the area of about five miles square, where the clouds around and about, and to the east of the fire, again

made their appearance, while in every other quarter it was clear. Now, said I to one of the company, "if Espy's theory is worth anything, we should have a shower of rain."

The clouds now began to grow more massive, and repeatedly changed color, giving decided evidence of an approaching storm. In a few moments more the rain began to fall, first in large crystal drops in exact imitation of an evening sunshine shower, and then a heavy dash of rain descended, which wet us to the skin, and continued until the fire was extinguished.

For weeks before there had not been a cloud to be seen, and at the time the rain was descending there were no clouds to be seen, except on the island in the immediate vicinity of the fire; every place else was enveloped in clear, bright sunshine. The evidence that the rain was caused by the fire was unmistakeable, for with the fire came the clouds, with the clouds, the rain; and when the fire was quenched by the rain, all was again brightness and sunshine.

Respectfully, yours,

ABEL SHAWK.

J. P. ESPY, Esq.

ESPY'S THEORY OF STORMS.

To the Editors of the Cincinnati Gazette:

If the good people of Cincinnati were aware of the amount of instruction they would receive, and the new source of pleasure that would be offered to them in the contemplation of the phenomena of the atmosphere, by listening to the lectures of Professor Espy, they would, I am sure, give him a full and attentive hearing. The theory of the learned professor is, in my judgment, as clearly demonstrated as the laws of gravitation, in proof of which I submit the following:

Keene, N. H., is situated in a deep valley of some fifteen miles in length, and eight or ten in width, having the Monadnoc mountain and its range on the east, and a ridge of lofty hills on the west. Standing upon one of these hills, you look down upon the whole valley, which wears the appearance of having been at some time the bed of a lake.

In July, 1856, I had occasion, in company with a friend, to cross this ridge, and to pause on its summit to give a little rest to jaded animals. The weather was excessively hot. Not a cloud was to be seen, nor was there a breath of wind stirring. Looking to the southeast at a distance of some five or six miles, I saw a fire just kindled in a fallow of some acres in extent. The column of smoke ascended perpendicularly and unbroken. I had previously been somewhat familiar with Professor Espy's theory of storms, and remarked to my travelling companion that we would watch the progress of the fire; for that, according to the said theory, if that column of smoke and heated air continued to ascend, and was not broken off by an upper current, it must inevitably produce rain. Up went the column straight as an arrow, and anon it began to expand at the top and assume the appearance of cloud. This cloud, with its base stationary, expanded upward, and swelled as if a huge engine was below with its valve open for the escape of steam. The thin, white cap appeared; the color changed, and soon the rain began to descend.

It remained stationary for a few minutes, looming up higher and higher and widening on either side a few minutes, and then sailed off in an eastern direction, pouring down torrents of rain in its pathway. I do not know the exact time occupied in this process, but I do not think more than half an hour elapsed between the kindling of the fire and the time the rain com-

menced falling. All this time at my point of observation the sun was shining brightly, and, besides that one over the fire, there was no cloud to be seen, so that the whole process was plainly visible in the unobstructed light of day. I have ever regarded it as a perfect and undeniable demonstration of the truth of the theory, and I can no more doubt it than I can doubt the evidence of my senses. I give it over my signature, hoping to call the attention of our citizens to the present opportunity of listening to the living voice of that venerable man, whose name future ages will place alongside of that of Franklin in the world of philosophers.

J. D. WILLIAMSOM,

Pastor of the First Universalist Church.

OCTOBER 30, 1856.

19. M. Dobrezhoffer, in his account of the Abiphones of Paraguay, vol. 3, page 150, says: "I, myself, have seen clouds and lightning produced from the smoke over the tall grass and bulrushes, as it is flying off like a whirlwind; so that the Indians are not to blame for setting fire to the plains in order to produce rain, they having learned that the thicker smoke turns into clouds, which pour forth water."

The bad philosophy of supposing that the smoke turned to cloud does not invalidate the evidence here furnished, that rain was produced by the fire.

Baron Humboldt gives, as an instance of what he calls the *mysterious* connexion between volcanoes and rain, the fact that when a volcano breaks out in South America in the dry season, it turns it, while the volcano is in blast, into a rainy season.

In his Views of Nature, page 366, speaking of Vesuvius in the last great irruption, he says: "The long drought which had parched and desolated the fields before the irruption was succeeded towards the termination of the phenomenon by a continued and violent rain, occasioned by the *volcanic* storm which we have just described. A similar phenomenon characterizes the termination of an irruption in all zones of the earth. As the cone of cinders is usually wrapped in clouds at this period, and as the rain is poured forth with more violence near this portion of the volcano, streams of mud are generally observed to descend from the sides in all directions." It is worth while to inquire whether the mud volcanoes, as they are called, are not generally of this nature; and especially, whether the deep gullies produced in the sides of volcanic mountains by water, are not caused by meteoric rivers falling from the clouds, as described and explained in my work on storms, rather than by water overflowing from the crater, especially where the irruption is attended with flames, for an irruption of water and flame at the same time seems impossible.

In the work above referred to, from page 492 to 518, are detailed many other facts of a similar nature, all going to show that rains may be produced in time of drought; it remains now to try the principle on a large scale, to see whether it may not be economically used to benefit mankind.

From the above generalizations, it appears that all rains in the United States travel to the eastward from the place of beginning, and that rains and snows in the winter are of great length north and south, and comparatively narrow east and west, and of course travel side foremost.

20. Now, if masses of timber, to the amount of forty acres for every twenty miles, were prepared and fired simultaneously every seven days in the summer, on the west of the United States, in a line of six or seven hundred miles long from north to south, then it appears highly probable

from the theory, though not certain until the experiments are made, that a rain of great length, north and south, would commence on or near the line of fires; that this rain would travel towards the east side foremost; that it would not break up until it reaches far into the Atlantic ocean; that it would rain over the whole country east of the place of beginning; that it would rain only a few hours at any one place; that it would not rain again until the lower air becomes charged with vapor, and the upper air has radiated off the heat which it received during the rain from the evolution of the latent caloric of the vapor condensed in the formation of cloud, which effects could hardly be produced in less than a week; that it would rain enough and not too much in any one place; that it would not be attended with violent wind either on land or on the Atlantic ocean; that there would be no hail nor tornado at* the time of the rain, nor intermediate; that there would be no destructive floods nor injuriously low waters; that there would be no oppressively hot nor injuriously cold weather; that the farmers and mariners would always know in advance when the rains would commence, or nearly so, and when they would terminate; that all epidemic diseases originating from floods and droughts, would cease; that the proceeds of agriculture would be greatly increased, and the health and happiness of the citizens much promoted.

These, I say, are the *probable*, not certain, results of the plan proposed—a plan which could be carried into operation for a sum not amounting to half a cent a year to each individual in the United States.

If this scheme should appear too gigantic to commence with, the trial might be made along the Alleghany mountains: let forty acres of four ten-acre lots be fired every seven days through the summer in each of the counties of McKean, Clearfield, Cambria, and Somerset, in Pennsylvania; Alleghany, in Maryland; and in Hardy, Pendleton, Bath, Alleghany, and Montgomery, in Virginia. The ten-acre lots should be, as nearly as convenient, from one to four miles apart, in the form of a square; so that the up-moving column of air which shall be formed over them may have a wide base, and thus may ascend to a considerable height before it is leaned out of the perpendicular by any wind which may exist at the time; and even with this precaution it will be useless to fire the materials unless it is nearly calm.

The summer rains at present are local, and of very limited extent; and though they travel towards the east like the winter storms, they are not extensive enough to cover the whole country in their progress; hence portions of the country are liable to be parched with drought and hot weather. May it not be possible that this irregularity is in part produced by the irregular burning of fallows and prairies, thus producing partial and irregular rains, interrupting the wide-extended and general rains, which would otherwise take place as they do in winter?

There is at present, and will be for many years to come, a vast amount of timber cut down in clearing lands, and burnt every summer, in the western parts of the United States; enough, perhaps, to produce the wide-extended rains, so much desired, without any expense. Until the public mind is prepared to carry into effect the above plan, I recommend to all persons who have fallows to burn, or other large masses of combustibles, to save them till the first very dry spell in the summer; and, to insure simultaneous action, let all west of 87° of west longitude set fire to their materials only on a Thursday, those west of 90° in the morning at 10 o'clock, and

* No hail or tornado ever takes place in widely extended rains, nor at any time when the dew-point is kept down by frequent rains.

those east of 90° at 6 in the evening; and let all east of 87° set fire to their materials only on Friday, those west of 77° at 10 in the morning, and those east of 77° at 6 in the afternoon; and in no case let any fallows be burnt unless it is calm, and at least a week has elapsed without rain.

I hope this request will be complied with, not only because all are interested in the probable result, but because it will be attended with no expense; and the best time of burning is in very dry weather.

It is not at all probable that all will be ready to burn on the first dry spell, or even on the second or third; and thus on every Thursday and Friday during the season on which there may be a drought materials enough may be burnt to produce a general rain.

21. For some time after these general rains partial rains cannot take place, both because of the scarcity of vapor left in the air, and because any up-moving columns of air which may be formed will not rise very high before they enter into the stratum containing much of the latent caloric given out by the condensed vapor of the previous rain, in which the up-moving columns cannot swim; and it is only after the lower air becomes charged with vapor, and the upper air becomes cooled by radiation, that another general rain can be produced, and it is not probable that either of these is effected in less than about seven days after a general rain.

As soon as the generalizations contained in this report shall be established as universal laws, on sea as well as on land, it will be easy to lay down rules to the mariner, to take advantage of the knowledge thus acquired.

For example, in the West Indies, from latitude 10° to 20° north, where it is known, from the valuable labors of Redfield, that great storms move along the surface of the sea from southeast to northwest,* the mariner will know that a storm is coming upon him whenever the wind sets

* I have shown in my *Philosophy of Storms*, from theoretical views, that it is probable that the upper air in low northern latitudes moves towards the northwest, which would be a reason for the storms there moving in that direction. It has been thought by some that the fall of an immense quantity of ashes on Barbadoes, in 1812, upon an eruption of a volcano in St. Vincent, proved that the current of air, at a great elevation, in the torrid zone, is from the west towards the east. But when we consider that the force of a rapidly rising column of air is great enough to cause the upper parts of this column to puff out even against a strong wind, we are warranted, from this circumstance alone, in rejecting the above inference, especially as we have no evidence that ashes did not fall at the same time west of St. Vincent.

In the two following accounts the ashes were carried to great distances in all directions:

In the fifth volume, part second, of the *Journal of the Geographical Society*, page 387, we have an account of the eruption of the volcano of Cosigüina, in Nicaragua, on the 17th of January, 1835.

In Truxillo, about 200 miles to the north, showers of ashes fell; and in Leon, 100 miles to the south, the district was enveloped in the most fearful darkness, terrific reports at the same time being heard, and showers of calcined lava were precipitated over the whole face of the country; and on the 23d the darkness spread with astonishing rapidity throughout the department of Nicaragua, several hundred miles to the southeast. The Columbian galley Boladora, which left Acapulco, in the Pacific ocean, near 1,000 miles west-northwest from the volcano, experienced the darkness at twenty leagues from the shore, and such a copious shower of dust that the crew were apprehensive of being suffocated, and were occupied forty-eight hours in clearing the vessel with spades. At Kingston, and other southern ports of Jamaica, more than 800 miles east-northeast from Cosigüina, the sound was at first supposed to proceed from the British man-of-war Fly, cast on the Pedro bank, but the ashes which subsequently fell speedily proved that a volcano was the origin.

In my work on the *Philosophy of Storms*, pages 11 and 19, an account is given of a dreadful volcanic eruption in the mountain of Tomboro, island of Sumbawa, eastward of Java, which commenced on the 5th of April, 1815, and was most violent on the 11th and 12th. Out of a population of 12,000 persons only 26 escaped destruction. Violent whirlwinds swept away men, horses, cattle, and everything which came within their vortex; tore up the largest trees, and covered the neighboring sea with floating timber, which, from its scorched appearance, had evidently been carried through the flames of the volcano. The volcano carried its ashes 40 miles to the east, 200 miles to the north, and 300 to the west, and how much further is not known. It was also accompanied with very great darkness.

It is also probable that the volcano of Cosigüina was attended with a violent up-moving current of air, as a forest, which

in strong from northwest, and that the only means he has to avoid it is to make sail to the northeast or southwest. He will know, also, that when the wind changes round to any south or southeast direction the centre of the storm has passed him, and will not return; consequently, as soon as it is moderate enough to hoist sail he may do so without fear: but as the storms in low latitudes move slow he must not sail directly with the wind, for fear of coming into the midst of the gale by sailing faster than the storm itself moves. In the Atlantic ocean, between the United States and Europe, though the winter storms are of such great length from north to south, and move side foremost towards the east in such manner that the mariner cannot sail around them, yet he will know when a storm is coming by the wind setting in from some eastern direction, (with a sudden rise of the barometer above the mean,) and when it changes round to some western direction (with a sudden rise of the barometer) he will know that the middle of the storm is passed, and that it will not return. Again: in whatever part of the world he may be, he has only to know in what direction storms move in his locality; and if the wind sets in from the opposite direction, and blows with considerable force for some hours, he will then know that a storm is coming upon him, and he will be able to shape his course accordingly. If he is in those regions where the storms are not very extensive, as in the East Indies and West Indies, he will, by sailing out of the way, be able to avoid the violence of the storm altogether.

23. There is a region near the northwest coast of Africa called the "rains," or calms," where it rains every day, with a breeze blowing for some time and then dying away. The mariner is sometimes detained in this region for weeks, without being able to get out. Might not this evil be remedied by sailing as close to the wind as possible whenever it springs up, and thus, receding further and further from the central region of the rains, where the calm prevails, and towards which the wind blows in all directions?

I have thought it not improper to say this much in relation to the practical utility of the theory of storms contained in this report. The intelligent mariner who shall make himself acquainted with the theory will be able in a short time to ascertain whether it is true or false, and, if true, to frame for his future guidance many other rules besides those laid down here. (For more particular directions, see No. 145, and subsequent.)

To enable me to deduce the generalizations given in this report, it was necessary to make a meteorological chart for each day in the year; and in case of storms, frequently two charts for

appeared to be as old as creation, was found to have disappeared, and a large tree was found fixed upside down in a newly-formed island or shoal.

M. Lartigue, page 71, says a great quantity of grasshoppers fell on the deck of his ship in latitude $20^{\circ} 33'$ north and $55^{\circ} 50'$ west longitude, and from the direction of the upper current of air, as ascertained by the clouds for several days during their fall, he infers they came from Africa.

He says, page 70, quoting *Annales Maritimes*, tome 10, page 582, that "on the 1st of May, 1812, ashes fell on the island of Guadalupe in the evening, and in Barbadoes a little after noon. It is known that a volcano in St. Vincent threw out these ashes on the preceding night."

Système des Vents.—Now Guadalupe is north of St. Vincent, much further off of St. Vincent than Barbadoes, which is east. This fact is very precious.

The eruption of volcanic matter continued to take place at St. Vincent from 3 o'clock till 6 on the morning of May 1, 1812; about 7 o'clock very low clouds composed of ashes reached Barbadoes, at 1 p. m. similar ones began to overspread Martinique, and in the evening a shower of dust fell at Guadalupe. As the last mentioned islands are situated, one at thirty-six and the other at seventy-five leagues to the north of St. Vincent, the ashes could not be carried to the three islands by the same west wind.

It is stated in the New Annual Register for 1812, that two English vessels within twenty miles of Martinique experienced from the same eruption similar effects to those observed at Barbadoes.—*Journal Meteorological Society of Great Britain*, p. 296.

one day, at different hours. This system having now been continued for four years since the last report, the charts have become so numerous that the expense would be very great to have them all engraved. I have therefore culled out of the whole fifty-eight for this report, and these contain all the storms of considerable magnitude which occurred in the United States during the period of the investigation—sufficient, I think, to justify me in deducing the generalizations given above.

I will only add, that nothing appears on any of the unpublished charts inconsistent with the theory and deductions contained in this report. Some of the storms, it is true, are contained entirely, for a time, within the bounds of my observers, and in that case the minimum barometer does not exhibit itself in a line of great length, extending from north to south, but it is confined to a region near the centre of the storm, and travels with that centre towards the eastward.

24. One of the most interesting questions remaining to be answered is, why are summer storms so local and sparse, altogether unlike the winter storms, which, by moving side foremost, sweep over the whole United States from west to east?* I find, by examining the summer charts not published, that seldom a day occurs in summer without rain in some part of the United States; but observers are too sparse to ascertain whether these rains are continuous from day to day, as the winter storms are. The astronomer is, in some measure, independent of his fellow astronomer; he can wait in his observatory till the star he wishes to observe comes to his meridian; but the meteorologist has his observations bounded by a very limited horizon, and can do little without the aid of numerous observers furnishing him contemporaneous observations over a wide extended area.

25. From the united efforts now being made by the Navy Department and the Smithsonian Institution, a much more extended and numerous correspondence in meteorology has been secured; and it is believed that, under these auspices, in a few years the various questions suggested in this report will be answered, and the science of meteorology established on the firm basis of legitimate induction.†

26. In my work on storms, pages 30, 35, and 37, I have given several tables of experiments on the degree of cold produced both in dry air and in moist, by sudden expansion from diminished pressure. In those experiments, however, the air was first condensed, and then, after it acquired the temperature of the room, it was suffered to expand suddenly by opening a stop-cock, and letting the air fly out of the vessel‡ in which it had been condensed by means of a pump, until equilibrium of pressure was produced within and without, and at that moment the stop-cock was closed, cutting off the communication between the air in the vessel and the atmosphere. The air in the vessel, at the moment of the greatest cold produced in it by expansion, being thus insulated, was made to act on a syphon barometer gauge, which rose on the outside leg connected with the atmosphere, and sunk on the inside leg connected with the air in the vessel, as the heat went in to restore the equilibrium of temperature which had been disturbed at the moment of expansion. After equilibrium of temperature was produced,

* Is the cause, as suggested in No. 20, the irregular burning of fallows in the summer? If so, man, by his ignorance, produces the droughts.

† Since this was written, the Commissioner of Patents has united with the Smithsonian Institution in pursuing the same subject, and some of the telegraphic companies are lending their aid.

‡ This vessel, with its gauge and pump, I called the nephelescope.

which was always effected in two or three minutes, the difference of level in the two legs was carefully measured with a scale divided into parts of fifty to the inch, by which I was enabled to estimate this difference nearer than one-fiftieth of an inch. My chief object in these experiments was to ascertain the difference of cold produced in moist and dry air for similar expansions and different dew-points.

27. I had previously calculated how many degrees a given quantity of vapor in the air would prevent the air from cooling, if it were all condensed in the air, by the evolution of its latent caloric. Calculating the result on the supposition that the specific gravity of vapor is five-eighths of that of air, the specific caloric of air 0.267, and that the latent and sensible caloric of steam or vapor is a constant quantity, equal to 1242 at zero of Fahrenheit; and allowing, also, 140 degrees for the latent caloric of fluidity in case the temperature falls below 32° , and using Biot's table of dew-points in the Edinburgh Encyclopedia, I had found that for each hundredth of an inch of elastic force of vapor in the air, the air would be heated a little more than one degree of Fahrenheit by the condensation of its vapor and the evolution into the air of the latent caloric of elasticity and of fluidity which it contained. Thus, when the dew-point is between 57° and 58° , at which temperature the quantity of vapor in the air is one-hundredth of its mean weight, it is known that this vapor, being condensed into water, would heat one hundred times its weight of water $13^{\circ}.82$; and $13^{\circ}.82$ divided by 0.267, the specific caloric of air, gives $51^{\circ}.76$, the elastic force of vapor being at this dew-point between forty-eight and forty-nine one-hundredths of an inch.

The experiments mentioned above accord well with this calculation; but as the specific caloric of air at different densities was unknown, and as the air was first condensed before it was expanded, and when expanded remained still superior to the common atmospheric air in density, I was desirous of making a series of experiments in which the expansions should commence with the air at common densities.

28. This series I never had an opportunity of commencing till the beginning of the year 1850. I then found a convenient place in the Smithsonian Institution to perform these experiments; and during their progress every facility was afforded by Professor Henry, the Secretary of the Institution, who also frequently attended to witness the experiments, in which he took a deep interest.

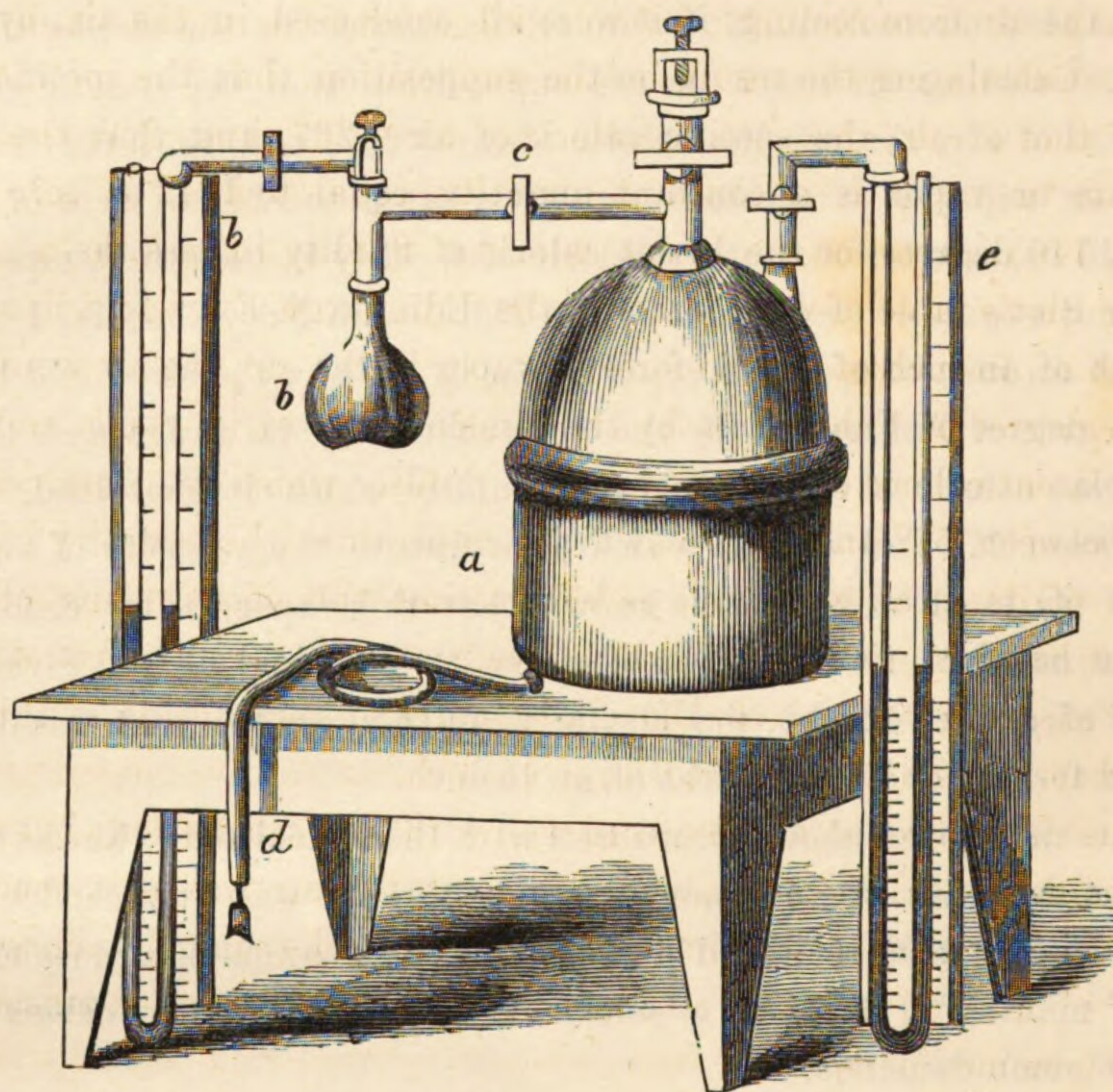
29. In entering on these experiments, I hoped I should be able to discover the exact law of cooling in the atmosphere for given expansions, both of dry air and of moist; both of air *under* the base of forming cloud and *above* the base, at all heights, as it ascends in storms from the surface of the earth to the top of the atmosphere.

In this hope I have not been disappointed. The law of cooling for all the different dew-points due to expansion from diminished pressure in ascending currents will hereafter be known, at least within very narrow limits; and from this law a number of most important corollaries may be deduced, as will hereafter be shown, when the reader is made acquainted with the manner of performing the experiments.

30. The instrument which I have employed in making these experiments I call the *double nephelescope*. It consists of two vessels, a large (*a*) and a small (*b*), united together in such a manner that a communication between them may be made or cut off at pleasure in the tenth of a second, by means of a stop-cock (*c*.) The large vessel is of copper and the small of glass, and

their relative sizes are about as 25 to 1. When the stop-cock between the vessels was closed, either of the vessels could be exhausted to any desirable amount, by connecting it to an air-pump, by means of a leaden tube (*d*;) or it could be charged with condensed air in the same manner by changing the leaden tube to the other side of the air-pump.

THE DOUBLE NEPHELESCOPE.



31. My first object in these experiments was to ascertain the law of cooling in dry air for different expansions. For this purpose I closed the cock between the vessels and exhausted the air in the large vessel, and measured the degree of exhaustion by means of a barometer gauge (*e*), noting the temperature of the room at the same time by a standard thermometer hung on the outside of the large vessel. This temperature I assumed to be that of the air in the nephelescope, or of both vessels.

The air in the small vessel was now under common atmospheric pressure, and was rendered dry by some sulphuric acid in it, which was agitated and shaken through the air for some time. The cock (*c*) was then turned so as to open a communication between the two vessels, and the air rushed from the small vessel into the large, producing equilibrium of pressure between the two in about one second of time; at that moment the cock (*c*) was closed, cutting off communication between the vessels at the point of time when the greatest degree of cold was produced in the small vessel.

This vessel was furnished also with a barometer gauge (*f*), which, at the moment of closing the cock, stood at the same height as that of the large vessel; but, as the heat went in to restore equilibrium of temperature, the gauge of the small vessel changed its level, going down in the inner leg and up in the outer, from the increasing pressure of the air in the small vessel from

increasing heat. When equilibrium of heat was restored, which took place in two or three minutes after the discharge of air from the small vessel, the difference of the height of the mercury in the two gauges was carefully noted by means of a scale divided into 25 parts to the inch, by which a difference of less than one-fiftieth of an inch could be detected. Having thus the difference of the two gauges, which may be called (d), it is easy to calculate the number of degrees of heat which the air in the small vessel received in acquiring equilibrium of temperature after expansion, which is the same as the number of degrees of cold produced at the moment of expansion, whether that expansion was great or small.

32. If we call the height of the mercury in the gauge after equilibrium of temperature is produced (p'), and this highest temperature (t), and the height of barometer (p), and the change of height of gauge by change of temperature (d), then will the following formula give the degree of cold produced:

$$\frac{d \times (448 + t)}{(p - p')} = \text{cold produced by expansion.}$$

The expansion is ascertained by the formula $\frac{p'}{p}$. The above quantities are all taken in English inches.

33. For example: Let us take the experiment of the 14th March, given in the table, when the barometer was 29.78, the thermometer 72° , the gauge of the large vessel after explosion 17.11 inches, the gauge in large vessel after equilibrium of temperature 14.93 inches, and the change (d) produced by increase of heat 2.18 inches; then (d) 2.18 multiplied by ($448 + t$ 72), gives a product of 11,336; and this product divided by ($p - p'$) $29.78 - 14.93$, gives a quotient of 76.33° = the number of degrees the air was cooled in this experiment. Moreover, the expansion in this case was 0.5013; for $\left(\frac{p'}{p}\right) = \frac{14.93}{29.78} = 0.5013$ expansion.

In like manner are found the expansion, and cold produced by the expansion, in all other experiments where dry air under atmospheric pressure was expanded into rarefied air. The formula $\frac{p'}{p}$, used to find the expansion, is simply dividing the quantity of air discharged, by the whole quantity of air in nephelescope before expansion.

So in finding cold produced, dividing $d(448 + t)$ by ($p - p'$) only means dividing $d(448 + t)$ by the quantity of air remaining in nephelescope after explosion.

By these two formulæ thus explained, the expansion, and the cold produced by the expansion, are calculated in all the experiments made on dry air, both above and below atmospheric pressure. For example: On the 1st of March, the mean of four experiments, in which condensed air was used and exploded into atmospheric air, showed a condensation before explosion of 42.63 inches; and, after the explosion and equilibrium of pressure with the atmosphere, the mercury rose on the outer leg of the barometer gauge 6.465 inches during the time that the equilibrium of temperature was being restored: (d) was then 6.465, the temperature was $69^\circ.1$, and the barometer was 29.50; the whole quantity of air in the nephelescope after explosion, $29.50 + 6.465 = 35.965$ inches; and 6.465 multiplied by $448 + 69^\circ.1$, gives 3343.0515; and this last number divided by 35.965, gives $92^\circ.64$ = the quantity of cold produced by expansion. The quantity of air discharged was $42.63 - 6.465 = 36.165$ inches;

and the whole quantity of air in nephelescope before explosion was $42.63 + 29.50 = 72.13$ inches; and 36.165 divided by 72.13 gives $0.5014 =$ the expansion.

In experiments where condensed air was discharged into rarefied, the same formulæ apply; only care must be taken to observe whether the air (after explosion) remaining in nephelescope is denser or rarer than atmospheric air at the time.

34. For example: On May 8,* five experiments were made, in which the first two, after explosion and equilibrium of temperature, had the air remaining in the nephelescope a little denser than atmospheric air: these are marked (+). The remaining three had air in the nephelescope after explosion a little rarer than atmospheric air, and these are marked (—); and the mean of the whole five gives a density of only $0.08 +$ of an inch greater than that of atmospheric air at the time.

In these experiments, 29.925 inches of air were pumped into the small vessel, and 5.7855 inches were pumped out of the large one. On making the communication between the two vessels, all the air that had been pumped into the small vessel went out into the large one, except 0.08 of an inch.

The air which thus went into the large vessel caused its gauge to stand 4.46 below atmospheric pressure, it having stood before 5.7855 below, thus increasing the elasticity of the air in the large vessel 1.3255 inch. If the quantity of pressure which went out of the small vessel be divided by the increase of pressure (1.3255) in the large, it gives 22.51, = the number of times the large vessel is greater than the small. A correction, however, must be made in this calculation, on the following account: It was found, by careful observations, that the cooling effect of the expanding air in passing from the small vessel to the large was not so great as the heating effect of the condensation of the air in the large vessel by the introduction of more air from the smaller. In the above case, the temperature in the large was increased sufficient to increase the elasticity or pressure of the air in the large vessel 0.16 of an inch; and this correction being made, the size of the large vessel (containing $12\frac{1}{2}$ gallons) is about 25 times greater than that of the small.

35. It should be observed, however, that where the expansion is much greater than 0.500, the cooling effect from expansion more nearly balances the heating effect from condensation; and when the expansion is 0.6667, the balance is exact. The probability is, that these two effects would balance one another when the expansion is 0.5000, if the air, in passing through the tube which connects the two vessels, did not catch up caloric in its passage from the sides of the tube; which it certainly does, to an amount which cannot be measured.

36. It is gratifying, however, to know that the amount is not very great, otherwise the cooling effect from expansion would be so much diminished that it could not balance the heating effect when the expansion is pushed to 0.6667. I say it is gratifying to know this, for it proves that but little heat is communicated to the air in the small vessel from its contact with the sides of the vessel during the very short period of its discharge—certainly much less than is imparted to the air passing through the tube. The air which passes through the tube must come, every portion of it, in contact with the sides of the tube in its passage, whilst but a small portion of the air in the vessel is in contact with its sides during the expansion, and the time of the discharge is too brief for much cooling effect to be produced by radiation.

* See table.

37. The discharge in no case, I think, lasted more than one second of time; and during the discharge but very little agitation was produced in the air, as was manifest in the experiments on moist air in which cloud was formed. This cloud, in some cases in which condensed air was used, remained visible and dense for two minutes and a half after the explosion; and in all cases this cloud was so little agitated that it disappeared by gradually settling to the bottom of the vessel, evidently by the gravity of the particles of water of which it was composed. The slightest agitation of the air in the vessel could have been detected by this cloud, but none was ever seen beyond a very gentle undulation, and that not always.

38. What was more remarkable still, the equilibrium of temperature was always effected nearly in about a minute; and at this time the cloud remained quite dense, and had not settled by its own superior specific gravity more than half way to the bottom of the vessel; and when it settled down entirely, the middle part of the bottom—which, by its convexity, reached above the small quantity of water that had been introduced into the vessel to cause the air to be saturated with vapor—was found to be thickly studded with particles of water, which had evidently been deposited there from the cloud.

39. This is a most instructive fact, though entirely unexpected, and goes far of itself to prove, and, in connexion with other phenomena hereafter to be mentioned, *absolutely* proves, that the air in the nephelescope, in heating up after explosion to its original temperature, *does not raise the dew-point with it to complete saturation.*

40. I ascertained a number of years ago, and stated in my Philosophy of Storms, (page 36,) that air confined in a vessel with some water in it, and kept in a room of uniform temperature, though the vessel should be heated up many degrees above that temperature when first placed in the room, so as to insure complete saturation, will gradually lower its dew-point below the temperature of the air in the vessel; and that in about fifteen days the dew-point will be from four to five degrees below the temperature of the air in which it is placed, and, of course, lower than the air in the vessel to the same amount; and that beyond fifteen days the dew-point ceases to become any lower, while the temperature of the air remains the same. I first suspected that something of this kind occurred, from some experiments I was then making to ascertain how much less air at a certain dew-point was cooled than dry air for a given expansion.

41. I found, on comparing a great many experiments together, that, in all those experiments that were made after the nephelescope had stood charged with condensed air many days before the expansion was allowed, the degree of cold was much greater than in similar expansions and temperatures in experiments made only a few hours or minutes after the condensation was made. On consideration, it appeared that this could only be accounted for on the supposition that less vapor was condensed in those experiments that produced a greater degree of cold; but this could not be if the dew-point was the same in both cases. I therefore instituted a set of experiments to test the fact directly. I placed a thermometer and some water in a glass bottle, and having heated it many degrees to insure saturation at the inferior temperature, I placed it in a room which was kept at nearly the same temperature, many degrees lower than the point to which the bottle was heated before it was placed there. I corked the bottle, and, in many trials, I found, when I withdrew the cork some hours only after the beginning of the experiment, and introduced another thermometer a degree or two colder than the one in the bottle, it was immediately covered with a film of condensed vapor; but the longer I let the bottle stand, up to

from twelve to fifteen days, the colder must the introduced thermometer be to cause the vapor to be condensed upon it. The ultimate difference was between four and five degrees.

Humboldt says, in his Personal Narrative, vol. 2, page 94: "In the heaviest rain, even in the midst of clouds, the hair hygrometer often keeps at 90° and 95° . In this case, the air between the drops of water or vesicular vapor is far from being saturated. Saussure once observed his hygrometer at 84.7° during a very heavy shower, and M. Deluc found that his hygrometers, which, plunged into water, marked 100° , kept at 83.3° when they were placed under a glass jar filled with atmospheric air, and of which the sides were constantly moistened with water."

Since writing the preceding paragraph, I made some observations on the dew-point and temperature of the air during rain, with the following remarkable result: At the beginning of the rain, (2 P. M. of the 12th April, 1851,) the temperature of the air was 59° , and dew-point 42.85° ; at 5 P. M. the temperature of the air was 58° , and dew-point 48.1 ; and at $6\frac{1}{4}$ the temperature of the air was 55° , and dew-point 49° ; though at this last observation it had been raining hard for two hours before. The next day, also, after it had been raining fifty minutes, the temperature of the air was 64° , and the dew-point 45° —that is, 19° below the temperature of the air. I consider it established, then, that air in contact with water in a glass vessel *will not saturate itself with vapor, or, if saturated, will cease to be so to the amount of $4\frac{1}{2}^{\circ}$ in fifteen days.* In thirty days I did not perceive any further depression of the dew-point below the temperature of the air.

42. Is the attraction of water for vapor, or of water for water, the cause of this phenomenon? It is known that out at sea the dew-point is generally five or six degrees below the temperature of the surface of the ocean, and air in contact with that surface. Why does not the water in contact with the air charge this air with vapor to saturation, and keep it constantly saturated?

43. In crossing the Atlantic, in 1840, I found, by repeated trials with a thermometer having its bulb first covered with a rag wet with sea water and swung in the air, and next wet with fresh water and swung in the air, that its depression below the temperature of the air by the cooling effect of evaporation was the same in both cases. From this it follows that *evaporation from sea water is the same as the evaporation from fresh water under the same circumstances.* This want of saturation of the air with vapor over the surface of the ocean does not, therefore, depend on the nature of sea water as being different from that of fresh water. As the dew-point cannot be higher than the temperature of the air, and as it is known that the temperature of the atmosphere is about one degree lower for every hundred yards in height to moderate elevations, it follows that the pressure of the vapor is much less above than below, as a fall of temperature of twenty degrees diminishes the pressure of the vapor one-half, and forty degrees three-fourths, &c. Does the elasticity of the vapor generated at the surface of the sea push it up through the pores of the air to regions where the pressure of vapor is less, with such rapidity of motion as to leave the lower parts constantly unsaturated? There are various phenomena in nature which enable us to draw the conclusion that this cannot be the case, and, of course, to answer the above question in the negative.

44. If the vapor below were to push itself up by its own elasticity to regions of low dew-point, it would be condensed into cloud there, and this cloud would be diffused there all over the sky; for, on this principle, the vapor would penetrate upwards everywhere alike in the same locality,

and everywhere it would meet a cold sufficient to condense a portion of it into cloud. If clouds were thus formed, they would exhibit a very different appearance from those which actually do form; instead of large cumuli with flat bases forming in the shape of hay-stacks, reaching sometimes with their tops ten miles high above their bases, surrounded everywhere throughout their whole extent with clear sky, we would have one continuous cloud of uniform thickness and appearance covering the whole heavens night and day.

45. Wishing to put this principle to the test of direct experiment, I fitted two retorts together in such manner that there was a free communication from one to the other through their necks. In one I placed a few drops of water, and immersed it in hot water, at the same time surrounding the other with snow. After things remained in this position for an hour and a half, I examined the result, and found that the retort, which had been surrounded with snow, was slightly moistened within; but, as far as I could judge, none of the water had been distilled over from the retort which had been surrounded with hot water.

This was tried repeatedly with the same result. I next took a glass tube about two feet long, with its internal diameter about one-third of an inch, bent at one end in the shape of a shepherd's crook, and hermetically sealed at the short end; into this tube I put a few grains of water, marking with a file how high the water reached in the tube; I then plugged up the open end with chloride of calcium, and excluded the outer end of this calcium from contact with the atmosphere; but the internal part of the calcium was separated from the water at the other end of the tube by nothing intervening but the air in the tube. Now, in this arrangement, a film of air, touching the chloride of calcium, would be made perfectly free from vapor at one end of the tube; at the other, a film of air touching the water would be as near saturation as evaporation from water could make it; and, at a temperature of 80° , the pressure of the vapor at one end of this tube was near half a pound to the square inch; and, at the other end, no pressure at all. Knowing that air with vapor in it is specifically lighter than dry air, I placed the end of the tube containing the water above, which I could easily do, without decanting the water on the chloride of calcium, in consequence of the curvature of the tube. I placed the tube in this position to prevent the vapor from passing to the chloride of calcium by convection, or by the motion of the air itself, and to compel it to pass, if it passed at all, by permeation.

At the end of three months the water was not sensibly diminished, and the chloride of calcium was not sensibly moistened in any part. Another tube in all respects similar to the above, except that the chloride of calcium was not used, was placed in a similar position; and, at the end of three months, the water was sensibly, but very slightly, diminished. A third tube in all respects similar to the last, except in its position, was employed at the same time, with the open end upwards; this had lost about the eighth of an inch of its column of water—a much greater quantity than the second tube had lost. These experiments were performed in a room which varied but little from the temperature of 70° Fahrenheit night and day.

To try the effect of high temperature on forcing vapor through the pores of air, I placed a tin cup of water on the top of a stove, which was employed in heating the room, and into this water I thrust the end of one of these tubes containing water, marked as before with a file, having the open end sloping downwards. During this experiment, which was continued four days, the water in the tin cup frequently rose to near the boiling point, and evaporated so fast that the

tin cup had to be filled up repeatedly during the experiment. During all this time there evaporated from the water in the tube only about one-eighth of an inch.

Again: in the summer of 1849, Dr. Foreman, of the Smithsonian Institution, at my request, placed two tubes similar to the above, except that they were only a few inches long, in the Smithsonian Institution—one with the open end uppermost, the other with the open end downwards. Those tubes have now remained in that position thirteen months; and from the tube with the open end downwards there has evaporated only one-third of an inch, and from the one with the open end upwards there has evaporated only one inch and one-tenth.

46. From these experiments it may safely be inferred, contrary to the general belief of scientific men, that *vapor permeates air from a high to a low dew-point with extreme slowness, if, indeed, it permeates it at all*; and in meteorology it will hereafter be known that *vapor rises into the regions where clouds are formed only by being carried up by ascending currents of air containing it*.*

Any one who chooses to take the trouble may easily make himself familiar with the manner in which up-moving currents of air carry up the vapor with them, by watching large cumuli forming in a clear sky in a hot summer day. While the cloud is increasing in size, which it sometimes does with great rapidity, he will see the top, in whatever direction it may be from him, rise rapidly towards the zenith, especially if he looks at it with a telescope. He will also frequently see a thin film of cloud form suddenly just above the top of the cumulus, evidently produced in the air above the cloud in consequence of that air being pushed up by the ascending current of the cumulus so high that the cold of expansion, from diminished pressure in its upward motion, sinks its temperature below its own dew-point, and this condenses a portion of its vapor into cloud.

47. By watching the phenomena now carefully through a telescope, or even without one, if the observation is made in a range with some stationary object, this newly formed cloud of thin texture will be seen to move upwards, but with a slower motion than the dense bright top of the cumulus, which will overtake the thin cloud above and amalgamate with it, sometimes even penetrating entirely through, showing its dense bright top above it, and surrounding itself with this newly formed cloud, something as a globe is surrounded by a wooden horizon.

48. This phenomenon is sometimes repeated two or three times before the cumulus rises to its extreme height; and always when a lofty cumulus is formed under cirrus, as the top of the cumulus approaches near to the cirrus, by lifting the stratum of air in which the cirrus exists, it changes the appearance of the cirrus entirely, thickening it, and destroying its hairy texture; and, by the time the top of the cumulus reaches it and penetrates it, the whole appearance is similar to that just now described.

49. The cirrus cloud is known to be a very lofty cloud, and it is generally thought to be the most lofty of all the clouds; and if its lower surface be spoken of, it is certainly much more lofty than the lower surface of any other cloud; but the tops of lofty cumuli always reach above

* The same inference as to the extreme slowness with which aqueous vapor permeates the pores of atmospheric air, if it permeates it at all, may be drawn from the known fact, that a thermometer with a wet rag round the bulb always sinks in dry air lower when it is swung rapidly in the air, than when it is at rest in still air.

From a little consideration it will be seen that, if vapor permeated the pores of air very rapidly, the thermometer with wet bulb would sink lower at rest in still air, than it would when it is swung rapidly in the air; for in case of being at rest, it would be surrounded by a film of air of its own temperature; but in motion it would constantly come in contact with air warmer than itself.

it, and, in penetrating it, always produce the appearance just described. Indeed, *the cirrus is generally, if not always, formed out of the top of the rain cloud*—the base of the rain cloud being all rained out, and the top left quite dense and dark at first, but in a few hours thinning out into that hairy appearance, from which it receives its name.

50. This thinning out is no doubt partly effected by the gradual descent of the particles of ice, of which it is composed, sinking down through the very rare air in which it exists, into warmer air below, and partly evaporating in this increased temperature; and many of those fibres which appear stretched out horizontally are really filaments hanging down perpendicularly, formed by portions of the particles that outstripped the others in their descent. It is not necessary to inquire, as is frequently done, *by what power are the clouds suspended in the air*, unless it can be shown that they are suspended, of which I think there is no probability.* In the nephelescope the particles of the cloud begin to fall the moment they are formed; and when the air is highly rarefied they fall to the bottom in much less time than when the air in which they are formed is much more dense. We have every reason to believe, then, that the particles of cloud begin to fall through the air, from their greater specific gravity than the air in which they exist, as soon as they are separated from the up-moving column of air, by means of which the cloud was formed.

51. Any one who watches the clouds will find that *every cloud is either a forming cloud or a dissolving cloud*. While it is connected with an up-moving column it increases in size and is dense at the top, and well-defined in its outlines; but, when it has no up-moving column under it, it begins to diminish in size and density, and becomes ragged and thin in its borders; and if it is large, and has a flat base while forming, it soon ceases to have a flat base when dissolving.

52. Moreover, when the particles of a cloud descend by their own gravity into warmer air below, and thus begin to evaporate, they absorb caloric from the air in which they evaporate, and thus diminish its temperature and increase its specific gravity, not only by their own weight, but also by the cold thus produced, and then the remaining particles of cloud will not only descend by their own weight, but they will go down along with the air thus made colder and heavier; and where the cloud is of considerable size, thus dissolving, and approximates near the earth before it is all dissolved, it will create a wind of considerable force, blowing out in all directions from under the cloud at the surface of the earth. *This explains what the farmers call wind clouds*. But there are many other phenomena in meteorology going to show that vapor does not permeate the pores of the air, and press itself upwards from where the dew-point is high to where it is low. There are regions of great extent in the torrid zone where it does not rain for many months, though the dew-point is very high below at the surface of the sea. Now, there is no place in the whole extent of these regions in which dense cloud would not be formed within ten hundred yards high, if the vapor at that height followed the same law of density as the atmospheric air.

53. It is true, in these regions, the lower half of the air is moving constantly in one direction,

* MM. Barral and Bixio, in their ascent through a cloud, on the 27th July, 1851, observed that the particles of the cloud were very thin plates of ice at great heights; and when they got to the top of the cloud, they observed that the sun was reflected from these plates as accurately as it is from the surface of perfectly still water; hence, they inferred, I think justly, that these plates were accurately horizontal at their upper surface. I do not know the cause of this horizontality, nor of the shape of the crystals.

and the upper half in another; but these adverse motions would not hinder in the least the motion of the vapor upwards through the air, if it could have this motion in still air, or in an atmosphere which was moving all in the same direction from top to bottom.

54. If it is asked why up-moving currents of air in these regions do not carry the vapor with them, and form rain clouds, as elsewhere, the answer is easy: though millions of up-moving columns may be formed every day, these adverse currents will prevent the columns from rising to great heights perpendicularly; for, as soon as they reach the upper current, their tops will be carried in a different direction from their lower parts, and, even if cloud should begin to form, it will be cut in two, and the up-moving force thus weakened and destroyed.

55. It is known that, wherever there is an up-moving current of air kept perpendicular until it reaches a great height, *there is rain as long as such current lasts.* During the whole summer, while the wind blows against the southwest side of the Himalayas, in India, there is rain below and snow above, to a very great amount, while on the north side there is no rain or snow, and the weather is extremely warm there. This great heat is produced by the great quantity of latent caloric evolved on the south side of the mountain by the vapor condensed there, and much of it congealed after condensation; so that the air goes over the top of the mountain containing the latent caloric, both of elasticity and fluidity, and showers down its heat by radiation on the northern slopes of the mountain, thus giving them a much higher temperature than they would otherwise have. In this manner the snows are accumulating in the summer on the south side of the mountain, and at the same time melting away on the north side by the abnormal heat; consequently, *beautiful fields of grain are growing on the north side of the mountain at the same elevation which on the south side is covered with eternal snow.*

56. So, while constant rain prevails on the Western Ghauts, in India, to the east, in the Decan, it seldom rains, and the temperature is so great that it seldom falls below 100° of Fahrenheit, even in the night. This great heat is said to reach a few miles into the bay of Bengal and there terminate suddenly. Is the hot air above the cloud over the Western Ghauts, containing the latent caloric just evolved, pushed out only to this distance? Does it, after reaching this point, assume its normal direction in this latitude towards the north?

57. So, on the east side of the Andes, where the wind blows all the year from the east in some parts, it rains every day on the lower parts and snows on the upper parts. *Does not the snow lie much lower on the east side than on the west?* The books, as far as I know, do not answer this question.* But why is it not so hot at the foot of the west side of the Andes, where these eternal rains and snows prevail on the mountains, as it is in the Decan?

It is probable that this great heat is prevented by a current of cold water coming from high southern latitudes along the coast, and that the cool air spreads itself from this current over the land by its weight; and when it rises up the slope of the mountain to a certain height, not sufficient to produce rain clouds by the cold of expansion by diminished pressure, it is swept off towards the west by the warm wind which comes down from the mountain; and it is manifest that this air, which has just crossed the mountain, has so much caloric in it just evolved by the condensed vapor, that any columns of up-moving air which might be formed during the day on the west, on reaching this upper current would cease to rise; for, on rising, they would enter an

* Since writing the above, I have met with a table in Kaemtz's Meteorology giving the snow line on the east side of the Andes, in Chili, 4,853 metres, and on the west side 5,646 metres high, from 14° to 18° south.

air much warmer than themselves, and, of course, of much less specific gravity, in which they could not swim. Or is the lower air, west of the Andes, kept comparatively cool by the particles of cloud which are swept over the top of the mountain, constantly falling down by their greater specific gravity from the upper current into the air below, and then evaporating (and cooling the air in which they evaporate) by absorbing all the caloric from the air, which becomes latent in the vapor formed from these dissolving particles of cloud?

If this last question shall be answered in the affirmative by future observation, it will not only account for the comparative coolness of the air on the coast, but for the heavy dews which prevail there; and it will also furnish a more satisfactory reason for the air not rising on the west of those mountains so as to produce rain.

58. I have frequently noticed, when the clouds come from the west and the wind below at the surface of the earth comes from the east at the same time for a day or two together, that the dew-point rises while the temperature of the air sinks, which, I think, can only be accounted for by the descent of the particles of the cloud, and their evaporation in the lower air. The particles of cloud do descend whenever they are not kept up by an up-moving current of air; in descending into lower air they do evaporate; and, in evaporating, they do diminish the temperature of the air; and thus fully account for the phenomena in question.

It appears, also, in a report made by Colonel George W. Hughes to the Department of State, and published in the *National Intelligencer* of November 22, 1849, that, according to Mr. Moro, "the north wind, which frequently blows over the Isthmus of Tehuantepec," [south of that part of the Gulf of Mexico where the northers prevail,] "brings with it the clouds formed in the Mexican gulf, and these are discharged upon the low grounds of the Coatzacoacos, towards the northern side of the Sierra and its principal summits; whilst above the opposite slope, and over the plain which extends from the foot of the mountains to the shores of the Pacific, the sky remains constantly clear."

"On the northern side of the isthmus, at the mouth of the Huasacoalcos, the northers prevail from November till April. I have seen thirty ships stranded in a single norther in the month of March." Is the weather here, as it is in the Decan, very hot at Tehuantepec and along the southern coast of the isthmus, where it remains clear while a great rain is prevailing not far from them on the north, with a violent north wind in the Gulf of Mexico, blowing towards the place where the rain is falling; or is it cooled by the dissolving clouds, as suggested above? The books, as far as I know, do not answer this question.

However this may be, the fact of great rains occurring on the isthmus at the time northers are raging in the Gulf of Mexico seems to account for the northers themselves on the principle before explained. On the leeward side of all these mountains, near the summit, when there are great rains on the windward side, does the barometer stand above the mean, whilst on the windward side it stands below the mean?

The same question may be asked as to Norway and the western coast of North America during the winter rains: Does the barometer stand above the mean on the east side of the Rocky mountains and the Dofrefield mountains during these rains?

On the eastern side of these mountains, in the winter, the air is much colder than on the western side, and of course denser; therefore it seems highly probable that the air on the western side has a greater perpendicular altitude than on the eastern, and of course will roll

over in the upper regions from the west of the mountains to the east; and as the mountains will hinder the air below from flowing towards the west, which it would do if the mountains were not there, the wind will constantly press in below from the west to supply the deficit on the west side, caused by the overflow towards the east above. This view explains both the rains on the west side of the mountains in the winter, and the reason why the air blows below from a warm ocean towards a cold continent during the winter, *which would not be the case if the mountains were not there*. The same reasoning will apply to the northwest corner of North America, where there are almost continual rains during the winter with the wind blowing from the warm Pacific towards the cold land of the continent. I inferred from the great rains on the west of the Rocky mountains that, in consequence of the great quantity of latent caloric evolved by the condensation of vapor there and carried over the mountains by the air, it was probable that the mean temperature near the mountains on the east side would be found to be abnormally great, and such it has been found to be.—(See 194.)

59. When the sun is north of the equator in our summer the centre of greatest heat is also north; and, as the air is more rarefied along this line of greatest heat, it rises there, or (what is the same thing) it is pushed up by denser and heavier air on each side of it. Now, the air coming from the north of this line is constantly arriving at latitudes where the diurnal velocity of the surface of the earth is greater, and, of course, as is explained in the theory of the trade winds, from the nature of inertia, it will not at once acquire this new velocity; and, therefore, it will become a northeast wind—that is, one moving towards the southwest.

60. For the same reason, the air moving towards this line of greatest heat from the equator towards the north will constantly reach latitudes where the diurnal velocity of the surface of the earth is somewhat less than that which it has just left; and, from the nature of inertia, it will continue to move faster towards the east than the portion of the earth at which it arrives, and thus become a southwest wind, or one blowing towards the northeast. *This latter wind is a true southwest monsoon*, and it has been shown, by the valuable labors of Lieutenant Maury, to prevail during the summer with wonderful regularity in the Atlantic, where, previous to his investigations, it had hardly been suspected, though it ought to have been predicted, from the line of greatest heat being north of the equator. At the meeting of those currents there must, of course, be an upward motion of the air, without a whirl, whatever there may be in storms that are round.

61. Now, this upward motion of the air will cause a condensation of the vapor and constant rains over this zone, a few degrees north of the equator; and the evolution of latent caloric in the formation of cloud will expand the air in the region of the cloud, and above, causing the air to spread outwards above, towards the north and south, *producing a fall of the barometer under the cloud, and a rise above the mean on the north and south*; thus accounting for the known fact, that the barometer at a mean is about one-quarter of an inch lower near the equator than it is on the outer edge of the trade winds, where the mean of the barometer is greater than in any other part of the earth's surface, except, perhaps, in the frigid zones, near the poles.* During great rains over any extensive region, does not the barometer stand higher than usual all round those rains—some fifteen or twenty degrees from the borders of those rains?

62. The Canary islands are situated near the northern border of the northeast trade winds,

* See Nos. 94 to 106.

so that in the summer they are within the trades, and in the winter they are just beyond their northern border. Now, these islands furnish some very instructive facts on this subject. For example: the barometer stands higher in these islands—two or three lines French—than it does near the equator, and one line French higher than it does in Spain. Its mean maximum in these islands is in the spring and autumn, about the time that the northern limit of the northeast trade wind is exactly at these islands. During the whole year the upper current at the top of the Peak of Teneriffe blows from the southwest. During the summer, while the wind blows below strong from the northeast, they have no rain; in the autumn, when the southwest wind is about to commence below, this wind commences at Portugal before it commences at Madeira, and at Madeira before it commences at the Canaries; and in the spring, when the wind changes to the northeast trade, it commences at the Canaries before it commences at Madeira, which lies to the north of them. *The air, then, as we would suppose from theory, is pushed out below, both towards the north and south, from the northern border of the trades, where the barometer stands higher than it does either north or south of those limits.* When the wind is about to change in the autumn from northeast to southwest, the southwest current above gradually appears lower and lower on the Peak of Teneriffe, and finally down to the base of the mountain and to the surface of the sea. During this time a cloud appears on the southwest side of the mountain—first near the summit, and constantly for several days increasing in size downwards, and then, when the wind from southwest reaches down to the surface of the sea, violent rains take place; and during the only violent storms of which I have seen an account, on the island of Teneriffe—November 6, 1826*—*the wind blew a violent gale on the north side of the island from the north, and on the south side of the island from the south, at the same time.* I think there can be no doubt that the high barometer at the outer edge of the trade winds is caused by the overflowing of the air from the region of great and constant rains in the torrid zone, first on one side of the equator and then on the other, and to the great dryness of the air there in its descent. It is worthy of remark, that on the northeast side of Canary island, at Las Palmas, the hottest month in the year is October; whereas on the south side of Teneriffe, St. Cruz, the hottest month is August. If it shall be found, on examination, that great rains fall on the south side of Canary island in October, the latent caloric evolved into the upper air on the north side of the island will account for this high temperature.—(See Ann. de Chem., vol. 22, page 281 to 300, and vol. 58, page 209, and Espy's Phil. of Storms, 404.) Kaemtz also says (page 358) that storms are frequent at Madeira in winter, when the limit of the northeast passes into the vicinity of this island; whilst, in the region of the trade winds, storms appear to be as uncommon as rains. If it shall be found, as I think it will, that the dew-point is much lower in the belts of high barometer on the outer borders of the trade winds than it is either more north or more south of these belts, then, as dry air is heavier than moist, the high barometer in these belts is partly due to the dryness of the air.

63. As the temperature of the air in these regions of constant rain is about 80° over the Atlantic, with a dew-point of about 75° , having an elastic force of about 0.80 of an inch, it contains latent caloric enough, if it should be all condensed by the cold of expansion from diminished pressure in its upward motion, to heat the air containing it about 80° —that is, hinder it from cooling to that amount in its upward motion. Now, it appears from experiments with the

* See my work on storms, page 404.

double nephelescope, that if dry air, under mean pressure, at the temperature of 80° Fahrenheit, should expand into three times its bulk, or 0.6667, it would sink in temperature about 108° ; and by the time it reached the top of the atmosphere, according to this ratio, it would sink in temperature about 163° . But as the experiments show that there is a small increase of cold above this ratio as the expansion becomes greater and greater, it may be safely inferred that *if dry air, at the temperature of 80° Fahrenheit, be expanded into vacuum, its ultimate temperature will be about, or not far from, 90° below zero of Fahrenheit.* Now, we know not exactly the lowest temperature at which vapor can exist in the atmosphere, but we are sure, if any exists at a temperature of 40° below zero, it is a very minute quantity. We are equally sure that a small quantity *does* exist at a temperature of 10° below zero.

64. Now, if we suppose all the vapor to be condensed in the upward motion of the air, then the latent caloric evolved would hinder the air from cooling to the amount of 80° , and its ultimate temperature at the top of the atmosphere would be about 10° below zero, at which temperature a small quantity of vapor still remains in the air; therefore all the vapor is not condensed in this case, but a small quantity remains in the very air which reaches the top of the atmosphere, and yet the temperature is reduced below 20° minus.

It may be asked, then, why does not the vapor continue to condense, throughout the whole progress of the upward motion of the air, to the very top of the atmosphere, whenever the air contains so much vapor that it cannot all be condensed by the whole cold of expansion? for when three-fourths of the vapor is condensed in the case under consideration, the air in the cloud is then 60° Fahr. warmer than air on the same level on the outside of the cloud, and, therefore, there is no doubt that its upward tendency is then greater than at a lower point in the cloud. Why does it not continue to condense its vapor to the top of the atmosphere, which it must reach, and thus cause the tops of clouds in the torrid zone to reach the top of the atmosphere?

65. The answer is plain from the experiments; by them it is shown that, as the air gets thinner and thinner in its upward motion, the cold produced by a given expansion becomes less and less; and, of course, whenever it reaches a height where the cold of a further expansion of air is less than that of the expansion of vapor which it contains, in the further upward motion of the air, however much vapor it contains, no more of it will be condensed. From the experiments, and especially from the following, it may safely be inferred that this point is between the point where the barometer would stand $6\frac{1}{2}$ inches high and where it would stand 5 inches high.

I caused moist air, under a pressure of eight inches of mercury, to expand suddenly from the small vessel into the large, where there was a pressure of four inches, and a *very slight cloud* was formed, which very speedily disappeared. I then caused moist air, under a pressure of $5\frac{1}{2}$ inches, to expand suddenly from the small vessel into the large, where there was a pressure of $3\frac{1}{2}$, and *no cloud* was formed.

In both the above cases care was taken to have the air in the small vessel fully saturated. The vessel was heated up many degrees and then permitted to cool down to the temperature of the room (82°) before explosion.

66. The reason why no cloud is formed in this case will appear more fully by the following example: If air, under a pressure of $5\frac{1}{2}$ inches of mercury, is expanded into double the space, it would be cooled about 15° ; the vapor in that air, however, even if it is saturated, would be cooled about 17° ; of course, the air cooling less than the vapor, no part of the vapor would be

condensed ; therefore, from this point upwards to the top of the atmosphere, no cloud would be formed. This is the reason that the *top of the highest cumulus, after it has turned to a nimbus or rain cloud, spreads out, like a mushroom, nearly horizontal above* ; and this is the part of the rain cloud which forms the cirrus after the rain is over, the lower part of the cloud being all *rained out*. By watching this cloud after the rain, this upper part will be seen to become thinner and thinner, partly by spreading out in all directions, and partly by the sinking down of the particles of which it is composed, by their specific gravity, into warmer air, where some of them, and finally all of them, evaporate, and thus the cloud very slowly disappears.

The books speak of the cirrus "thickening before rain;" but every part of a cirrus becomes thinner constantly from the moment of its formation till it disappears.

67. *The reason why the cirrus is dense before rain* is, that on the near approach of the rain cloud, cirrus more and more recently formed comes into view ; and when the rain cloud comes very near, the cirrus shows itself to be, as it really is, a part of the storm cloud itself, thrust out above by the expansion due both to the evolution of the latent caloric by the condensation of the vapor into cloud, and to the greatly diminished pressure then upon it.

The evaporation of the particles of cirrus at these great heights, even when they descend into air not entirely saturated, must be very slow, from the extreme cold that prevails there. Captain Parry found that it required four hours to dry in the sun a silk handkerchief at Winter Harbor, lat. 75° , on the 5th March, the temperature being at the time from 18° to 6° ; and this was the first article that had been dried for six months without artificial heat, and it was a month longer before flannel could be dried ; also, there was no snow nor rain from November to February inclusive, the barometer varying but little from the mean, 29.85 inches, the lowest temperature being 55° below zero, and much of the winter being calm.

Now, the particles in a cirrus cloud, even in the torrid zone, are always in a temperature not much above zero ; and, besides, no doubt in air frequently nearly saturated with vapor, in which the evaporation must be very slow.

68. It is stated in the books, and seems to be the general opinion, that the upper trade wind, which presses outward from the torrid zone towards the poles, carries with it an immense quantity of vapor, to produce rains in high latitudes and moderates the cold there by the evolution of the latent caloric which it carries with it. But this cannot be the fact, for the air, before it rises over the equatorial regions to one-third of the height of the atmosphere, condenses nearly all its vapor into cloud, as has just been shown ; and therefore, when it rises above the cloud and rolls off to higher latitudes, it carries with it but little vapor—in extreme cases of high dew-point only about one-third of what it contained at the surface of the earth or sea over which it ascended. In short, *the air above does not carry as much vapor to high latitudes as the air below to low latitudes.**

*In the equatorial regions, where it rains nearly all the year, the air is so nearly saturated with vapor that the evaporation is very small—much less than in the region of the constant trades, where it seldom or never rains, and where Humboldt found the degree of saturation constantly less and less on receding from the region of the rains towards the north ; and the maximum of dryness was near the northern border of the trade winds, for at higher latitudes the air again was more nearly saturated.

This dryness of the air near the northern borders of the trade winds, no doubt, is produced by the descending currents of the air in those regions where the barometer stands above the mean, and where, of course, the air must sink down and push itself to the north and south below by its superior weight. It is known, also, that the surface of the sea near the equator is less salt than it is in the region of the regular trades, which plainly depends both on the great rains and little evaporation near the equator. [See 176.]

It is thought, also, that this upper trade wind, when it reaches higher latitudes, by some process not clearly explained, produces rains in its descent to the surface of the earth.

69. But this cannot be; for if the air over any portion of the earth in the temperate zones were to descend from the upper regions to the lower, it would be able to contain below, merely from the heat of compression, at least four times as much vapor as it contained above, even if it had been saturated above before it commenced its descent. *So far, then, from this upper trade wind producing cloud when it descends as low as the region where clouds are formed, it causes the air there to be extremely dry.* It is thought by some that the air being extremely cold in the upper regions, when it descends into the lower will cause clouds to form by mingling with warm humid air below. But neither can this be correct; for though it is true that the air above, when it descends through the lower air by its specific gravity being greater, must of course contain less caloric to the pound than the air through which it passes—for it would not descend on any other principle*—yet it is easy to show that this difference must in all cases be very minute, for so mobile is the air that whenever the upper air, which on first going up contains the latent caloric given out by the condensation of the vapor, and is therefore sometimes 60° warmer than it would have been in going up without any vapor in it to condense, has radiated its heat into space, so as to contain a very minute portion of caloric less than an equal weight of air below it, the equilibrium is destroyed, and the air above begins to descend by its greater specific gravity, and in passing through the air below will constantly increase in temperature as it descends, by increasing pressure; so that if it was one degree colder above than its normal state, it would continue one degree colder than the air through which it passed all the way down to the surface of the earth, provided it received no addition of caloric from surrounding air. This difference of temperature is quite too minute to produce clouds by intermingling with the air below.

But even if a case is supposed, which certainly never occurs in nature, that the air descending is 20° colder than the air through which it passes, then must this air have been so extremely cold—more than 100° below zero before it commenced its descent—that it may be safely assumed that it contained no sensible portion of vapor; and when it came into air below—say at the temperature of 32° —even if you suppose this air saturated when these two airs mingled in equal bulks, the mean temperature of the mingled mass would be 22° nearly, and the dew-point would be reduced to 13° ; that is, 9° below the temperature of the mingled mass of air.

70. *Clouds cannot be formed in this manner—that is, by descending masses of cold air.* Besides, if you suppose they could so be formed, then it would follow that the lower the cold mass of air descended, the more cloud would be formed by the greater quantity of vapor near the surface of the earth, and the densest portion of the cloud would be in the hollows, to the great inconvenience of vision. *Nature is not so contrived.* Again: if clouds were formed by descending currents of cold air, the wind would be found at the surface of the earth to be blowing outwards in all directions from the storm cloud, exactly contrary to what is shown to be the case in this report in all wide-extended storms. So, also, if storms were produced by descending columns of cold air, *the barometer would rise under the middle of the storm cloud*; whereas it always descends there, though in some cases it rises under the borders even where there is much rain.

71. Again: if cloud was formed by a column or current of cold air mingling with warm humid air in its descent, *the cloud would be hollow*; for it could only mingle with the air in con-

* Except it has a lower dew-point, and of course a greater specific gravity.

tact with its outside, and not at all near its centre. The cloud would in like manner be hollow, if it was formed by the mingling of a warm current of air moving upwards with cold air through which it passed, for it could only mingle with air on its outside, and not at all in its middle parts, which would not come in contact with the surrounding cold air; but clouds are not hollow, but more dense in their middle parts.

72. *Hail cloud* especially could not be formed by the mingling of a cold downward current with the warm air below; for then drops of water formed in the cloud could not be carried upwards above the line of perpetual congelation, so as to freeze into masses of ice, containing in them sometimes all kinds of materials evidently taken up during the storm from the surface of the earth. Now, these masses of ice could not be formed by condensation of vapor above the line of perpetual congelation; first, because of the very small quantity of vapor in the air at that height and temperature; and second, because whatever particles of vapor are condensed in a temperature below 32° will be frozen in the form of snow, and these cannot unite so as to become large masses of clear ice.

Nor can the *tornado cloud* be formed by a descending current of cold air mingling with warm moist air below; for then it could not carry up to a great height heavy bodies from the surface of the earth, and keep them up until they are sometimes carried fifteen or twenty miles, and then permit them, sometimes *covered with a thick coating of ice, to fall along with a heavy shower of hail.*

73. Nor could a *whirl* in such cases prevail unless it was very near the centre; for if it did these heavy bodies would be whirled outwards from the centre by the centrifugal force, unless, indeed, the whirl were confined to a very narrow space in the centre of an up-moving column caused by the evolution of latent caloric from the condensation of the vapor, as before explained. Such a whirl (I state in my work on storms, page 329) is entirely consistent with the inward and upward motion of the air, which certainly exists in this meteor; and I will add here, that one phenomenon frequently accompanying the pillar of condensed vapor under the tornado cloud, namely, that it appears hollow, seems to favor the idea that where this appears there is a whirl in the centre, by which the particles of condensed vapor are thrown outwards from the centre by the centrifugal force.*

74. Or is this light appearance in the centre of the pillar caused by a *constant flood of electricity passing through this column of rarefied air*, thus increasing its rarefaction by the addition of the repulsion that the electrified particles of air would thus have for each other? To my

* This pillar of condensed vapor itself, as I showed in the Journal of the Franklin Institute, might be formed by the great rarefaction and cold produced by a whirl near the centre of a waterspout or tornado, even in cases where the rarefaction, without a whirl, would not be sufficient to cause the cloud to be formed low enough to reach the surface of the earth or sea. In my Philosophy of Storms, page 30 of the introduction, I have given an account of many experiments on water running through a funnel; and in all instances where care was taken to have the water still, before removing the finger from the lower end to let the water run out, it discharged the whole contents *without any whirling motion*. The same thing occurred whether a funnel was used or a tub with a hole in the bottom. Whenever there was the least perceptible whirl in the water before the commencement of the flow of water below, the whirl was produced; and then, in all cases, the length of time in discharging the whole water through the opening below was increased by the whirl. I add, also, in the same page, that I first supposed all spouts whirled, and was only *compelled to abandon this notion by the facts themselves*. If it should be found that a stream of electricity is constantly descending or rising in the middle of the spout, then the air will be rarefied there more on that account; and if it shall hereafter be established by observation that the barometer falls more than three inches in the middle of a spout, then some other cause is concerned in this great depression besides the evolution of latent caloric from condensing vapor—perhaps electricity.

mind this is a much more rational view of the mode of action of electricity in this meteor than any I have ever heard proposed. Yet even with this mysterious agent I find it difficult to conceive how the *garments can all be torn from men and women, and turkeys and geese and chickens entirely stripped of their feathers*, without hurting the bodies of either, on the passage of this meteor; yet such is undoubtedly the case in very many of them.

75. The idea which has been suggested, that heavy bodies are drawn up from the surface of the earth by the attraction of positive electricity above for these bodies negatively electrified below, as light bodies play up and down between metallic plates differently electrified, *seems to me entirely unphilosophical*, because there is nothing in the upper regions of the air to correspond to the upper plate. The air itself cannot be that plate, because action and reaction being equal and in opposite directions, the air above, on this supposition, would be drawn down with a velocity as much greater as the air below is drawn up, as the air above is rarer than the air below; and we are sure that at the top of the cloud, which reaches, when the dew-point is high, to where the air above is only about one-fifth of the density of the air below, there is no downward motion of the air at all.*

76. Besides, the air is always charged with positive electricity in the upper regions, and with negative at the surface of the earth; and it is only when there is a lofty column of cloud, reaching with its base near the surface of the earth, and with its top a region of highly rarefied air, that electricity plays its fantastic freaks. Is this lofty cloud merely a conductor of electricity? The experiments of Faraday show that the electricity of steam issuing from a steam boiler is not generated by the condensation of the steam, but only by the friction of the issuing steam and water against the sides of the tube.

77. I have repeated a large number of these experiments, to satisfy myself of their accuracy or inaccuracy; for I acknowledge I did hope, at the commencement of these experiments, I might, by varying them, be able to show at least that the *expansion* of steam, if not its *condensation* into water, would develop electricity; but in this attempt I failed, and I freely acknowledge that *all my experiments went to confirm Faraday's results*.

78. Is the electricity of the upper air produced by the friction of the wind in storms, which passes to the upper regions after rubbing against the irregularities of the earth's surface, heightened by the friction of rain through the air? The present state of science, or at least my knowledge of it, does not enable me to determine this question with absolute certainty in the affirmative; but I think the following considerations render it probable, and at least worthy of future inquiry. A dense cloud is undoubtedly a better conductor of electricity than clear air; and the higher the top of a cloud reaches into the upper air, which is more highly charged with positive electricity than that below; also the more dense the cloud is—that is, the more vapor is condensed in it—and the nearer its base is to the ground the better conductor it is. Now all these circumstances take place in the summer, when the dew-point is very high, and that is the time when thunder is the most violent. This view of the subject is confirmed by the fact, that *during the winter season* the upper regions of the air are much more highly charged with electricity than during the summer; for the dew-point being low in the winter the tops of the clouds are then not near so lofty as in the summer, and the electricity of the upper regions is then much more perfectly insulated, and therefore it accumulates in the winter; for the friction

*See No. 66.

of the wind from which the electricity is supposed to be generated is as great at the surface of the earth in the winter as in the summer, and up-moving columns of air take place in storms at all seasons of the year, carrying up with them the electricity thus generated.

79. If it is asked *why we have no thunder in the winter*, though the tops of the storm clouds rise even in this season to a region where the air is at least considerably charged with electricity, perhaps the answer may be found in this—that the storm clouds in the winter are of great extent, and of course the tension of the electricity, being extended over a very large surface, is very feeble; and the substance of the cloud itself being framed out of vapor much less dense than that of summer clouds, this tension may not be able to strike from one particle of the cloud to the next adjacent one: no general discharge can take place.

Besides, even in the winter, during a very warm spell of weather, with a high dew-point for the season, we sometimes have a violent thunder storm from a cloud of very limited horizontal extent, *as the thunder clouds always are in the summer*. Such a cloud is in reality an insulated pillar of hot air, mingled with condensed vapor, having just given out into the air itself its latent caloric, causing the air at the top of this cloud, in many cases, to be 60° warmer at its top than the air on the outside at the same level. Has *thermal electricity* anything to do with the phenomena in question?

80. In my Philosophy of Storms, in the section entitled Meteoric Rivers, an account is given of *many columns of water, and sometimes of ice*, falling on the sides of mountains, cutting down holes where they fell—some only a few feet deep, others twenty and even seventy feet—and forming deep gullies all the way from where they fell to the bottom of the mountains.

For an explanation of the manner in which these meteoric rivers were formed, I refer to the work itself. I will only add here, that many of these meteoric rivers were seen in their fall, and they all appeared luminous like pillars of fire. There is little doubt that this luminous appearance was electricity (fire balls, which are described sometimes as falling by gravity) conducted down from the upper regions by the continuous stream of water there descending.

81. When the kite experiments mentioned before were performed, and the kite was allowed to stay up in the air many hundred yards high in the night, by touching with the hand the reel on which the wire was wound which was attached to the kite, the *fingers became luminous*, quite brilliant, though no sensation of a shock was produced; but by touching the wire itself, a very pungent shock was experienced; and one day in particular, when the kite entered the base of a forming cloud, the discharge of electricity down the wire, snapping to an iron conductor stuck in the ground, terminating at its upper end within an inch or two of the wire, became fearful.

In the case of the meteoric rivers, the friction of the water through the air in falling might be supposed to generate the electricity which rendered them luminous; but the friction of the wind on a kite eight feet square could evidently not be sufficient to account for the great quantity of electricity constantly passing down the wire; indeed, the shock on touching the wire became quite sharp when the kite was elevated a few hundred feet, even in a clear sky. *After all, it must be acknowledged that the utility of electricity is yet to be discovered; as also its mode of generation, and the part it plays in storms.*

The evolution of latent caloric in the formation of cloud is undoubtedly adequate to account for

all the phenomena attending storms, with but two or three exceptions noticed before, which may probably be produced by electricity—in a mode, however, not yet exactly known.

82. But it may be asked, is cloud never formed except where there is an up-moving column of air? The present state of science enables us to answer this question unhesitatingly, No. For, *air coming downwards always becomes dryer*; and if you even suppose that cold air on the same horizontal level should mingle with warm, so as to produce condensation of vapor, the evolution of latent caloric in this air would immediately diminish its specific gravity, and it would begin to ascend.

83. Besides, nature herself furnishes an answer of the most decisive character to this question. In those regions of the torrid zone where it is known that the lower trade-wind blows in one direction, and the upper in another—where mingling of the two strata would be likely to take place, if it ever takes place at all—it so happens there is no rain in particular seasons, unless in those *islands which have lofty mountains*, such as Jamaica, where it rains every day, even during the dry season; while in the ocean around, and even in those islands of the ocean and saharas of the continent which have no mountains, there is no rain; for any up-moving columns which may be formed by sea breezes over islands without mountains, *in the constant trade-winds*, will be bent out of the perpendicular by the prevailing wind before they rise high enough to form clouds of sufficient density to rain. Thus, in the very regions where cross-currents of air prevail, and, of course, where mixtures of different temperatures are most likely to take place, rains are not produced at all, unless some circumstance occurs, such as a lofty mountain or volcano, causing an up-moving current of air.

84. But one of the most beautiful contrivances of all these meteorological phenomena is, that wherever there is an up-moving column of air sufficient to form a large cloud, there is, of necessity, *a down-moving current of air all around it*; and, of course, as far as this down-moving current reaches, it is entirely clear, *for no clouds can form in a down-moving current*; and if any clouds existed in it at first, they would soon be dissolved by the heat of compression; for, being forced downwards by the outspreading of the air above from the cloud forming in the up-moving column, they would come under greater pressure in their descent, and the increase of heat from this cause would dissolve the cloud. Were it not for this cause, there are large regions in the torrid zone which would be covered with *eternal cloud*; for, the air pressing in on both sides of the torrid zone towards the line of greatest heat, as it is known to do, there would be a constant rising of the whole air for many degrees on each side of this line if it were not for the counter-acting influence of the up-moving columns all around their borders, which is the only thing that prevents a large portion of the torrid zone from being covered with eternal cloud; for it cannot be denied that if the air moved upwards *everywhere*, and at all times, in the torrid zone, it would carry up its vapor with it, and that, on reaching about as many hundred yards high as the dew-point is below the temperature in degrees of Fahrenheit, this vapor would begin to condense into cloud by the cold of expansion due to diminished pressure; and thus the inhabitants of the whole region would be deprived from ever seeing the sun and stars. This would be almost as great an inconvenience as if the densest parts of clouds were always on the surface of the earth; as they would be if clouds were formed, according to the imaginations of some men, by the mingling of cold currents of air coming down from great heights with the warm humid strata of the air below, or by warm humid air blowing from the south to colder regions

in the north, where it is cooled below its dew-point, and thus, as they imagine, forms clouds. If this latter were the plan that nature adopted in forming cloud, the thickest part of the cloud would undoubtedly be touching the earth or sea—it would be a dense fog reaching no great distance above the surface of the earth. *The very sudden change of temperature* which takes place as soon as the centre of the storm passes an observer, and the wind changes from southeast to northwest, as it sometimes does, proves of itself, if there was no other evidence, that, in this case at least, there is an up-moving current of air in the storm; otherwise the warm air which had been blowing for many hours from the southeast would be returned, and but little change of temperature would be experienced on a change of the wind. When the wind has been blowing from the northwest for a considerable time and then changes suddenly and blows from the south, the temperature does not suddenly change as in the case of change the other way in storms; for here there being no up-moving current, when the wind changes the same cold wind comes back upon us with but little change of temperature for many hours.

85. When De Luc (Ann. de Chemie, vol. 52) made his celebrated observations on the summit of Mount Buet, an isolated pyramid of the Alps, nine thousand feet above the level of the sea, and found the air extremely dry, while clouds were forming very rapidly on the same level with him over the valley, until the moment when he became enveloped with cloud, it did not enter his mind that there was an up-moving current of air to which the formation of the cloud was due; and he was extremely perplexed both with the *dryness* of the air and also to find, contrary to his expectation, that there *was an increase of temperature in the cloud*. He infers from these observations, confirmed by others made afterwards in company with Saussure, that clouds are not made out of aqueous vapor in the air, condensed by cold, but that they are produced by a decomposition of air itself. When he went to the top of this mountain with his newly invented hygrometer he expected to find the air on a level with forming clouds saturated with vapor; and, as soon as he should be enveloped in cloud, he expected to find a great increase of cold, which was the only known means of condensing the vapor in the air, though he did not pretend to assign any cause for the production of the expected cold. The existence of an up-moving column here explains the difficulty.

86. If any one will carefully observe when, after a very cold spell of weather, the south wind begins to blow, bringing a temperature, and even the dew-point, much above that of the surface of the ground, he will find *no clouds form that whole day*, unless fog on the surface of the ground be called cloud; nor do any appear in the sky, except perhaps the cirrus, which was formed a day or two before in the far west; because, the air near the surface of the earth being colder than the air at some distance above, no up-moving columns can be formed, though all the circumstances which have been thought by theorists heretofore to be favorable to the formation of clouds are known to exist; for, at the time this warm moist air blows from the south, it is known that the upper current is coming from the west in middle latitudes; and yet there is no cloud formed by the mingling of these two currents.

87. Besides, if everything was the most favorable for the formation of cloud by the mingling of those two—that is, if they were both saturated with vapor at very different temperatures in close approximation—any cloud thus formed would be of a flat, thin, pancake shape, at most, only a few hundred feet thick, and of great length and breadth, instead of being as they are, when formed completely by up-moving columns, many miles thick from their flat bases to their

flat tops. But even if a cloud of two thousand feet thick should be formed between these two currents, both being supposed to be saturated with vapor, it is known that the quantity of vapor is so minute, from the low temperature of the air at even the height of two miles, that the whole quantity of vapor condensed even on this most favorable supposition would not produce an eighth of an inch of rain if the whole cloud should *rain out* and none of the rain should evaporate in descending through the air below.

88. If cloud is never formed only in an ascending current of air, we would hardly expect to see clouds form when the ground is covered with snow, with the air above it considerably warmer than the freezing point, because, under these circumstances, *up-moving columns could hardly be formed*. This reasoning does not apply to the time when the temperature is raised by an approaching storm, as explained before; for, when a great storm cloud comes over a region where the air at the surface of the earth is colder than it is just above, as it would be in this case, and as it frequently is in the night, it overcomes the tendency of this cold air at the surface of the earth to lie still, or rather to settle down into the lowest hollows to which it is contiguous, thus rendering the hollows much colder at such times than the slopes of the hills a thousand feet higher up.

Occasionally, however, when the storm is very moderate and the barometer does not sink much on its passage, the colder air in the hollows may resist the up-moving power of the storm; and, in such case, it *may rain above and sleet below, or even hail*, by the freezing of the drops of rain on coming down into the cold air of the hollow.

In such case, the top of the cold air in the hollows becomes the true surface of the earth from which the in-blowing air rises under the storm cloud to furnish it with fuel to keep up its activity in its onward motion.

89. Professor Guyot told me that he has frequently known it to rain on the northern slope of the Alps, several thousand feet above the base, when, at the same time, the air below was many degrees below the freezing point; and that, *on ascending from the valley below he suddenly came into a warmer air*; and at this time the wind was blowing from the south across the Alps, producing great rains on the middle slope of the Alps, snow above, and, on the northern side, hail below—not those large lumps of ice which only fall in the borders of a violent up-moving current in hot weather when the dew-point is very high. It may be added that the heat of the air on the upper part of the northern slope depended, in part, on having come from the south, and partly on the latent caloric evolved by the condensation of the vapor in the air as it crossed the mountain.

In this respect it is like the air which crosses the Himalaya, as before explained; and, as I would infer from theory, *the air on the leeward slope of all mountains will be found on examination to be in time of rain on the windward side*.

90. Again: if clouds are produced only by up-moving currents of air, *cloud ought not to be formed in the region of greatest cold during the winter in North America and Asia*, for up-moving currents can hardly be formed there; and, from the report of the committee of the Royal Society on physics and meteorology, page 45, it appears that “there is a district in Siberia, mentioned by Erman, where, during winter, snow never falls *and clouds are unknown*.” Is this the case in North America over the region of greatest cold? Does the barometer stand higher in these regions than in the regions round about them?

91. Near the equator in South America, at Javita and San Carlos, where Humboldt says it

rains nearly all the year—from four to five months constantly without intermission, a small but very thick rain—he found the *temperature from nine to eleven degrees colder than it was a few degrees further from the equator*, just beyond the borders of the rains at Cumana and other places north of the Orinoco. He says: “The decrease of heat that is observed in approaching the equator is singularly conformable to the hypotheses of some naturalists of antiquity. It is, however, merely a local phenomenon, less owing to the height of the ground than to a constantly rainy or cloudy sky, the humidity of the soil, the thickness of the forests, the evaporation of the plants, and the want of sandy beaches, adapted to concentrate caloric and throw it off by radiation.”

92. “The influence of a sky veiled by vapors is manifest in the stripe of the shore of Peru, where no rain ever falls, and the sun, during a great part of the year at the period of the mists, displays itself to the naked eye like the disk of the moon. Between the parallels of ten and twelve degrees of south latitude the mean temperature is only $72^{\circ}.32$ Fahrenheit, about ten degrees below the mean of the latitude.” As to Peru, if it shall be found that the particles of cloud which cross the top of the Andes fall down into the lower air and produce the mist spoken of there, the cold of these descending particles, together with *the quantity of caloric abstracted from the lower air by their evaporation in it*, will have to be taken into account in explaining the low temperature of this region. In the region of constant, or nearly constant, rains, the cooling effect alone of the rain descending from a great height is sufficient to account for the cold at the surface of the earth. In Hindostan, *during the summer months, the temperature is lower in those parts where great rains prevail than it is in the dry months of winter*, though it is very much warmer in the summer than in the winter in those parts where it does not rain. This effect, I think, is due entirely to the cooling effect of the rain, and not at all to a greater evaporation, for there is almost no evaporation from the surface of the earth in time of rain. The cold in these rainy regions of the torrid zone is confined to the lower regions of the atmosphere, for the latent caloric given out by the great quantity of vapor condensed in the regions where the clouds are formed, keeps the upper regions at a temperature much above the mean of the climate, as is proved by the barometer, which stands constantly lower than a mean during these rains, showing that the upper air must be more above the mean temperature than the lower air is below it.

93. During the great rains in Hindostan the latent caloric evolved swells out the air in the region of the clouds and above, and causes it to pour itself over the top of the Himalayas, no doubt causing the air thus passing over, with the caloric in it just evolved, to press itself down the slope of the northern side some thousands of feet; and *if the mountains were removed, it would press itself back below towards the southwest, and then the southwest monsoon would not reach to such an abnormal distance to the north as it does at present, entirely from the existence of the mountains*, hindering the air from the north from flowing down towards the southwest, as it does elsewhere in these latitudes. Does the barometer stand above the mean on the north side of the Himalaya during the rains on the south of it? Theory says it stands above the mean on the top.

94. It is also well worth inquiry, whether the great depression of the barometer, noted by Captain Wilkes and other navigators, in high southern latitudes, may not depend on the continual rains, or rather snows, that prevailed there during the season of the year they visited

those regions? If it shall be found that the barometer does not stand low during other seasons when great and continual snows do not take place, then the cause here suggested is the true one. It is known that almost continual storms take place in the neighborhood of Cape Horn, and that the mean of the barometer there is very low—a fact altogether favorable to this suggestion. Kaemtz says that, “in the east part of Terra del Fuego, the weather is cloudy, rainy, and unsettled throughout the year; and in the west part of Patagonia the rain is continual, and the earth is never dry.” “These gales and incessant rains,” he says, render the summers of these countries very disagreeable, but the winters are very mild; and at Port Famine, one degree north of Terra del Fuego, the thermometer does not fall to the freezing point during the whole winter in latitude 53° south. The summers, it is true, are quite cold; for rains in summer diminish the temperature of the lower air, by the cooling effect of the drops of rain coming down from a cold region. At all events, the *almost incessant rains which prevail near Cape Horn and for some distance around, and the immense quantity of latent caloric involved, are sufficient to account for the very low barometer which is known to be common, if not universal, in that region.*

I have not been able to find any records of the barometer, and the weather generally during the whole year, in those high southern latitudes, in the zone of considerable extent, in which the barometer was found by Captain Wilkes, &c., to be constantly far below the mean, accompanied with constant gales and heavy snows; and, unless I have positive testimony to the fact, I shall not believe that the barometer stands lower at the level of the sea in the southern hemisphere than in the northern, *only in regions where great snows or rains prevail, and only while they do prevail.*

95. That great and almost constant rains or snows should take place in these high southern latitudes, appears probable from the following theoretical considerations:

It appears, from the reports of navigators attempting to penetrate these high southern latitudes, that a large region round the south pole is covered with eternal ice, and, of course, the lowest stratum of the atmosphere there in their summer will be about 32° Fahr. The whole column, therefore, of the air at the south pole and around it will be much colder and heavier than the column of air on the outside of the frigid zone; consequently, the top of the atmosphere at the pole, and for some distance around it, will not be so high as it is on the outside of this zone; and, therefore, the air on the outside of the zone, at the top of the atmosphere, will roll into the frigid zone on all sides towards the pole, carrying no vapor with it—for it can have none at great heights in these latitudes. Before this air reaches the pole, which will require several days, it will have radiated off its superabundant latent caloric which it had received in the region of the rains, and thus its specific gravity will be greater in the region of the pole, both on account of greater cold and greater dryness. The barometer will thus stand above the mean at and for some distance around the pole, and the air will press out from the pole on all sides below, and *in* towards the pole on all sides above; and rains or snows on the outside of this region of greater cold will be almost incessant, by the rising of the air there, from the diminished pressure caused by the evolution of latent caloric, and rolling over towards the pole above. If this is the true explanation of the continual rains and snows in high southern latitudes, it will follow that it never snows or rains at the south pole itself, nor for some distance around it; for, *where there is a constant downward motion of air, there can be no condensation of vapor.*

Of course, if there are any mountains there, however high, they are not covered with snow, and all the ice is frozen sea-water.

Sir J. Ross, when he reached latitude 77° south early in February, which is summer time there, found the temperature to vary from 12° to 14° , with a southerly wind, (page 237.)

If we assume that the temperature of the south pole during the summer should even be 32° at the surface of the sea, which is probably covered with ice, and the temperature of latitude 70° , 42° Fahrenheit at the surface of the sea, from the experiments detailed before, it will follow that the mean temperature of the atmosphere from bottom to top will be about 36° below zero of Fahrenheit, and, of course, will be less in bulk by $\frac{1}{41\frac{1}{2}}$ than air ten degrees warmer than itself. If to this we add the difference of temperature due to the latent caloric evolved by the condensation of the vapor at latitude 70° , where great rains and snows almost constantly take place, the difference may amount to 20 degrees more. Then the mean temperature of the air at latitude 70° will be 30° warmer than the air at the south pole during the summer; and, from the principles before explained, the air in equilibrium of pressure, without making any allowance for the difference of the dew-points, would stand higher at latitude 70° , $\frac{3}{41\frac{1}{2}}$ of the whole height, than at the south pole; but equilibrium of pressure in such case could not be established, for the upper air at latitude 70° would constantly flow towards the pole, and cause the barometer to sink below the mean at latitude 70° , and rise above the mean at the pole. If the flow above towards the pole is assumed to be infinitely rapid, the fall of the barometer would be $\frac{3}{41\frac{1}{2}}$ of 30 inches—that is, 2.18 inches; but, as this assumption is inadmissible, the barometer would not fall so much, probably not more than two-thirds of that quantity—that is, 1.46 inch, and about one-twentieth of an inch more for the difference of the dew points.

96. In conformity with this hypothesis, the wind in high latitudes near the borders of the ice ought to be found *blowing out from the poles* much more frequently and violently than inwards towards the poles; and not unfrequently, when rain or snow occurs in the open sea near the borders of the ice, it ought to be fair weather towards the poles, especially when the wind comes from that direction. That this is really the case, appears from direct observation of W. Scoresby, jr., who spent many summers in the arctic sea, near Spitzbergen, in latitudes 78° , 79° , and 80° . He says, page 297 of his *Arctic Regions*: “It is not uncommon for the ice to produce the effect of repulsing and balancing an assailing wind. Thus, when a severe storm blows from the sea directly towards the main body of ice, an *opposite current will sometimes prevail on the borders of the ice*; and such conflicting winds have been observed to counterpoise each other a few furlongs distant from the ice for several hours: the violence of the one being, as it were, subdued by the frigorific repulsion and greater density of the other.”

97. “During this period the largest proportion of snow is precipitated on the exterior of the main body of ice; hence, we can account for the fewness of the clouds, the consequent brightness of the atmosphere, and the rareness of storms in situations far immured among the northern ice.”

And in page 377, he says: “*Far within the borders of compact ice, the atmosphere in summer is often cloudless and the weather serenely pleasant, though cold; but in the usual fishing stations, and on the exterior of the ice in general, a clear sky is not frequent.*” In pages 403, 404, 405, he says: “The phenomenon that is most calculated to excite surprise is that several distinct and even opposite winds, with the force in many instances of a fresh gale, will occasionally prevail at the

same moment of time within the range of the horizon. An instance or two may not be uninteresting. During thick showers of snow on the 30th of April, we were sailing by the edge of a stream of ice, with the wind from the northwestward, and several ships were seen within the distance of three or four miles. As all of these ships were sailing 'on the wind,' it was easy to ascertain its direction where they were. Two ships bearing N.E. from us had the wind N. E.; two bearing E., at E. or E.N.E.; two bearing S.E. had the wind at S.E.; while it blew with us at N.W. In each of these situations a fresh breeze prevailed."

98. And again he says: "We were sailing in April, 1813, near the edge of the main western ice, in latitude $80^{\circ} 7'$; and while a gentle wind from the north prevailed with us, a heavy swell from the S.S.E. came on and a dense black cloud appeared in the southern horizon, which rapidly rose into the zenith and shrouded one half the heavens. The commixture of this dense air with the cold wind from the north, [according to Hutton's theory, which Scoresby adopts,] produced a copious discharge of snow. When the snow ceased, though we were nearly becalmed, we observed several ships a few miles to the southeastward, under close-reefed topsails, having evidently a gale of wind blowing in the direction of the swell. About two hours afterwards the southerly wind reached us, and, as we stood to the eastward, gradually increased to a gale. On returning towards the ice, however, at five o'clock P. M., the wind again subsided; so that when we came within four or five miles of it the sky cleared, and we were again becalmed. *From the clear atmosphere to the northward and westward, and the dense sky to the southward and eastward, with the heavy swell from the S.S.E., it was evident that we were between two winds—a southerly storm to the southward of us and a northern breeze to the northward.* At seven P. M. of the same day, a northeast wind commenced, and soon blew a tremendous storm." In the next page, he gives an account of "sailing near the borders of the ice in latitude 80° , and enjoying fine weather for two days; while several ships in latitude 79° experienced a most tremendous storm." He had, however, a constant fall of snow, consisting of the most beautiful crystals he ever saw, and a heavy southerly swell.

99. As to the temperature in these high northern latitudes—from 77° to 80° —it seldom rose to 32° at a maximum till June; was sometimes below zero from 2° to 4° as late as the 24th and 25th of April, and was frequently down at 10° and 15° in May, and sometimes as low as 18° in June. And the barometer, though it was very variable, always stood very high with clear weather and wind from the northward, *occasionally reaching 30.50 inches*; and during the whole month of May, 1815, the mean of the barometer was 30.11 inches in about latitude 78° and in longitude from 3° to 9° east; whilst in the same year, from the 1st to the 10th of April, in going from the 62d to the 76th degree of north latitude, *the mean of the barometer was 29.51—a difference of 0.60 inch in favor of the high latitudes*; this certainly favors the hypothesis that the barometer stands higher at the poles than a mean. Nor is this low barometer at about latitude 70° an accidental thing; for Kaemtz gives a table of the height of the barometer at Bosekop, latitude $69^{\circ}.58$ north, calculated by M. Bravais for the different winds, in which *the mean, at about the winter solstice, is 29.33, or about three quarters of an inch below the mean in the borders of the ice in latitude 78° to 80° .*

Erman traversed the ocean four times on different meridians from 55° north to 58° south, and made 14,000 observations, and he found the pressure of the atmosphere as follows:

Setting out from 60° south latitude and following the same meridian, the mean pressures go

on increasing up to the limit of the trade winds: that is to about 25° south latitude. From this parallel they regularly decrease to the equator, where they attain a relative minimum; they then increase anew to the northern border of the trade winds; and in our hemisphere the phenomena occur in a uniform manner as in the opposite hemisphere. The difference of pressure at the limits of the trade winds, and at the equator is 4.06^{mm} , from our eight passages across both zones of the trade winds; and this result has been confirmed by the observations of Sir John Herschel during his voyage to the Cape of Good Hope.

The difference between the mean pressures on the coast of Kamtschatka and Cape Horn are respectively 12.86^{mm} and 12.18^{mm} , inferior to the maximum at the borders of the trade winds; and this result is fully confirmed by a series of observations made on the coasts of Iceland.—*[Journal of the Meteorological Society of Great Britain, p. 276.]*

From the table at Bosekop it also appears that the northeast winds, though they blow off the sea, and in winter bring a much higher temperature than the southeast winds, which blow off the land, always cause the barometer to rise to the amount, at a mean, of 0.48 of an inch. This falling of the barometer with southeast wind, though it brings a greater cold, is probably produced by a storm of snow at sea near the coast, which may well be supposed to move in this region towards the northeast; and when its centre is nearest Bosekop, the barometer will be lowest with a southeast or a south wind. If it shall be found that the tide also rises higher at this time, notwithstanding the wind blows off shore, this fact will favor the suggestion.

100. If it be asked why the barometer stands much lower at a mean in latitude 65° and 70° south than in latitude 65° and 70° north, the answer will be found in the fact that in the south, in these latitudes, there is much more sea and less land than in the north, and also that the permanent ice extends further from the south pole than it does from the north pole; and thus the air which receives the latent caloric of the condensing vapor in the region of the rains near the borders of the ice, swelling up and rolling over towards the pole, having further to go at the south than at the north, will have greater time to radiate its superabundant caloric into space before it begins to descend; it will become colder at the south than at the north, and thus be of less altitude over the coldest region, and therefore more air will flow over above from the region of the rains towards the south pole and its immediate vicinity, where the depth of the atmospheric ocean is the least.

101. It appears also from Mr. Scoresby's investigations, in page 362, that during nine years of observation in the months of April and May, *the wind blew $2\frac{1}{2}$ times more frequent from the ice than towards it.*

All these facts observed by Scoresby, and especially the almost constant clear weather which was observed towards the pole, even when great storms of snow prevailed in the borders of the ice and further south, lead to the conclusion that the hypothesis assumed is true, viz: that a greater cold prevails at the poles, or near them, than at 10° or 15° from them; and if this hypothesis shall hereafter be confirmed, the cause of the great rains and snows near the borders of the ice, and of course of the low barometer there, is explained. I will merely add here that it is probably also that there is a greater difference in winter than in summer between the temperature of the air at the poles and at the borders of the ice; and, if so, there will be a greater difference in the height of the barometer at these two localities.

Sir J. Ross has shown also that there is a large prevalence of north winds over south in the

middle of North America, as low down as latitude 70° , and longitude $91^{\circ} 53'$ west, not merely during the winter, but in every month in the year. *The northern winds were not only more than double as frequent as southern, but more than double as strong; and he found southerly winds largely to predominate in latitude 77° south.*

He also found the mean of the barometer in latitude 70° north, in the middle of the continent, to be above 30 inches in May, October, November, December, and January, and a little below 30 inches during the other months of the year 1829.

102. In his last voyage of discovery in the southern hemisphere, page 210, Captain Ross says he was surprised to find his barometer to rise to the unusual height of 29.35 inches in a gale from the southward, in latitude $74^{\circ} 44'$; and by examining his journal, I find that from latitude 74° to 77° , (the highest latitude attained in the southern hemisphere,) *the mean of the barometer was more than half an inch greater than it was from latitude 66° to 70°* —which fact is also in favor of the hypothesis that the barometer stands still higher nearer to the pole.

In page 123, Scoresby mentions a remarkable fact, which I think strongly favors the hypothesis that while there is an outward current of air below from the pole, there is frequently, at least, an inward current above at no great elevation, containing a much higher temperature than that below. He says: "It is really extraordinary that inferior mountains, such as Ben Nevis, in Scotland, the elevation of which is only about 4,380 feet, should sometimes exhibit a crest of snow throughout the year; while in Spitzbergen, latitude 80° , where the mean annual temperature is about 30° lower than in Scotland, and the mountains little inferior in elevation, *the snow should sometimes be wholly dissolved at the most considerable heights;*" and he might have added, while there is much snow in the valleys below. And Martins says that "in Spitzbergen rain falls on the tops of the highest hills"—showing the high temperature of the air above.

103. In examining the tables of the South Sea exploring expedition, by Captain Wilkes, I find the barometer stood lowest from about 63° to 66° south latitude, at a mean about 29 inches; and *both north and south of those latitudes it stood higher.* He spent one day in about 67° , near the icy barrier, and the barometer on that day did not sink below 29.20 inches; and for several days, between 66° and 67° south latitude, the barometer stood above 29 inches; whereas between 63° and 64° , on one day, the mean of the barometer was 28.638; and in latitude 66° and 67° , near the icy barrier, the wind was constantly from the southward, blowing from the ice; but in about 59° and 60° south latitude, it prevailed from the northward; *and much snow fell in the belt between 60° and 65° latitude, towards which the wind blew on both sides.*

104. In passing from the northern to the southern hemisphere, and from the southern to the northern, Captain Wilkes constantly found the barometer fall below the mean on approaching the equator, and lowest of all in the belt of rains from 4° to 8° north latitude, and constantly rise above the mean on approaching the outer borders of the trade winds—thus confirming the observations of Humboldt and other navigators.

105. I find also, by examining his tables, that in this very belt of rains, where the barometer stands lowest, the temperature of the air is about 6° lower than it is beyond the borders of the rains both north and south—which is what Humboldt and others found before. From a remark made by Captain Wilkes in the introduction, it appears he had not been aware of this fact. I think there can be no doubt that the temperature of the lower atmosphere in this belt is reduced by the drops of rain coming down from above, where they are very cold, and yet the mean

temperature of the whole column of air, from the surface of the sea to the top of the atmosphere, is many degrees warmer than the columns on the outside of the rain, caused by the evolution of the latent caloric in the condensation of the vapor into cloud, as before explained.

There is no other way to account for the low barometer in this belt, where the air below is absolutely colder, which of itself tends to make the barometer stand higher.

106. *In the ocean, then, there are three belts where the barometer stands below the mean, with almost constant rain or snow—one near the equator, one near the arctic circle, and one near the antarctic.* These belts change their latitude some degrees with the seasons, following the sun. Are the belts of Jupiter produced in the same manner as these belts on the earth?

There are also, *certainly*, two belts in the outer borders of the trade winds, where the barometer stands above the mean, and *almost certainly* two regions more—one round the north pole, and the other round the south pole—where the barometer stands above the mean.

107. *Towards* the equatorial zone or belt of low barometer, the wind blows on both sides, causing the trade winds; and *from* the two belts in the outer border of the trades, where the barometer stands above the mean about one quarter of an inch, the wind on the equatorial sides blows towards the equator, and on the polar sides towards the poles, with great regularity on the side next the equator, but irregularly on the side next the poles, though showing a strong predominance in that direction, at least in the Atlantic, as shown by Maury's Pilot Chart. On each side, also, of the arctic and antarctic belt of low barometer and almost continual snows, the wind blows predominantly towards the belt, from the pole on one side, and from the temperate zone on the other. Much is said by meteorologists of atmospheric waves producing fluctuations of the barometer. They seem to think that the depth of atmosphere from the surface of the earth to its top is greater where the barometer stands higher.

108. They give no account how these waves are produced, nor why, unlike the waves of the sea, they remain stationary on each side of the trade winds, or travel sometimes fast and sometimes slow with storms. *The truth is, that the barometer always stands lowest where the atmospheric column stands highest, and vice versa, as has been explained before.*—(Art. 95) and (note to art. 16.)

109. It has also been frequently asked, why the wind does not blow in the whole northern temperate zone from the northeast, and in the whole southern temperate zone from the southeast, as the received theory of the trade winds would lead us to infer it ought to do?

The answer to this question is plain from the theory here given of the high barometer in the borders of the trade winds. The wind at the surface of the earth in the temperate zones cannot blow *towards* these belts of high barometer, but, on the contrary, must blow *from* them. And then, on the principle of the trade winds, as thus modified, these winds, as they pass to higher latitudes, where the diurnal motion of the earth is less and less, will become more and more western winds.

110. It is supposed, also, by some meteorologists that the upper trade wind comes down in the middle latitudes of Europe, and produces the southwest wind at the surface of the earth, which is known to prevail there; but it is manifest that this upper trade wind must come down in the very region *from* which the winds blow both to the north and the south at the surface of the earth; for these winds below can be supplied from no other place. And so far from the upper parts of the atmosphere north of the northern boundary of the trade winds below blowing towards the north, there must be a tendency of the air on both sides above to move towards the

region where the air is descending, and blowing out below. In short, air enough must descend in the outer boundary of the trade winds to supply both the currents below, which blow from each belt of high barometer towards the poles; for *there is no other source from which these currents can be supplied.*

111. Knowing that if air descends from a great height to the surface of the earth or sea, it would be very dry immediately on coming down, before it had time to receive any vapor from the sea, as before explained, *I was led to infer from theory that the air must be much drier in the belts of high barometer, near the outer borders of the trade winds, than it is either north or south of these belts;* and I was thus led to examine authorities on the subject.

I first examined Humboldt's writings, and found that, according to a table which he gives in page 91 of the second volume of his personal narrative, the quantity of vapor in the air was actually greater in latitude $30^{\circ} 36'$ north than it was in latitude $18^{\circ} 53'$; and at latitude $29^{\circ} 18'$ there was less vapor than in either of the above named latitudes. Unhappily no observations of the hygrometer are given in other intervening latitudes near the centre of the belt of maximum barometric pressure. These few observations, however, tend to justify the theoretic deduction that the air is drier in this belt than on either side of it. Theory also leads me to think it will be found, by future observations, that the dew-point is extremely variable in this belt; and that *on the outside of a rain storm, in this region, the dew-point will be found to fall suddenly, even below the mean;* for all round the borders of a rain storm the air is moving downwards with greater velocity than usual, as before explained; and, therefore, the approach of a storm of rain in these latitudes may be anticipated by a sudden fall of the dew-point, provided the dew-point is constantly observed.

112. This fall of the dew-point frequently occurs before rain in the summer at Philadelphia, in latitude 40° north, where I made my observations. I have known the dew-point to fall suddenly—that is, more than 10° in a few minutes—before a great rain, which came on in a few hours afterwards, though the dew-point had been nearly stationary for many days before, both night and day, at about 75° and 76° Fahrenheit. The first time I observed this phenomenon, so unexpected at that time, was not long after I began to observe the dew-point in 1827. I had been taking the dew-point a great many times every day and night during a very warm, dry spell of weather, with the hopes of being able to predict an approaching rain by a *rise* of the dew-point, when, on observing a sudden fall of several degrees, I utterly despaired of any rain until the sun should have time to raise the dew-point by further evaporation. What was my astonishment, when one of the most violent rains I ever saw came on in three or four hours after this fall of dew-point was observed! I am, however, not able to say that the dew-point did not fall an hour or two before it was observed. This phenomenon has been observed very many times since 1827; and *once in 1832 I observed, in Philadelphia, the dew-point 41° below the temperature of the air a few hours before a rain came on in a hot summer afternoon.* I relate this fact from memory, (not having my journal before me at present,) and I am unable to say how many degrees the dew-point fell during the few preceding hours, but it certainly fell many degrees. I think it can hardly be doubted that this low dew-point, which only sometimes takes place in the border of storms, is produced by the descent of air from great heights to the surface of the earth.

Nor is this descent necessarily attended with much change of temperature; for the air, as it

descends, comes under greater pressure and increases in temperature by condensation, and may thus correspond nearly, or even exactly, with the air below. Most generally, however, I have found the temperature to increase under such circumstances. The descent of air all round in the borders of a rain storm is always accompanied by a rise of the barometer, as before explained.

113. In my last report, No. 113, I stated that on examining the tables on this subject in Captain Wilkes' South Sea Expedition, I found that the dew-point was frequently noted *above* the temperature of the air, and that, therefore, no confidence could be placed in the journal, so far as the dew-point was concerned. I gladly embrace this opportunity of correcting this statement. On conversing with Captain Wilkes afterwards, I found I had not understood the manner that had been adopted in recording the dew-point, and now I have full confidence in the journal, and I have accordingly copied from it the following strong evidence on this matter:

The brig Porpoise, Cad. Ringgold commander, in going from latitude 13° south to Sidney, New Holland, had the dew-point never more than 17° below the temperature of the air till reaching $28^{\circ} 30'$ south, near Sidney, and then the dew-point suddenly fell and became very variable. On the first of December, 1839, at Sidney, about latitude 32° south, the temperature of the air at 9 o'clock, A. M., was 93° , and the dew-point 50° —that is, 43° below the temperature of the air, wind northerly and clear, and at 9 P. M. the temperature of the air was 64° , and dew-point 60° , with rain. On the third of December, at 9 A. M., the temperature of the air was 63° , and the dew-point 44° , clear; and at 9 P. M., the temperature of the air was 62° , and dew-point 30° , cloudy. After leaving Sidney, the dew-point between latitude 35° and $38^{\circ} 30'$ varied from 56° to 51° . What but a downward motion of the air from the upper regions of the atmosphere could produce a dew-point two degrees below the freezing in this hot region in the midst of their summer?

114. Wishing to have some confirmation or confutation of this deduction from my theory, I applied to the Secretary of the Navy, in March, 1851, for leave to go south far enough to cross the belt of high barometer, (which is known to be from 29° to 32° or thereabouts,) and my request was immediately granted. I consequently set out on my tour, going down the Mississippi to New Orleans, thence to Havana in the Gulf of Mexico, and then to New York by sea, so as to cross the latitudes in question both by land and sea. In going down the river, I commenced taking the temperature of the air and the dew-point at Louisville, and continued to make frequent observations all the way down to New Orleans—adding the temperature of the river after I reached the Mississippi.

On leaving New Orleans, on the 28th of April, for Havana, the same system of observations was continued in the Gulf of Mexico; and there, even in the night, observations were made every half hour by the officers of the steamer Falcon, at my request—for which kindness I desire here to return my sincere thanks.

115. On leaving Havana, on the afternoon of the 1st of May, the same system was continued, with the exception of a few hours each night, until I reached latitude $35\frac{1}{2}^{\circ}$. I thus crossed the latitude in question twice—once by land and once by sea. The phenomena in both cases were in conformity with the deduction I drew from theory before I set out on my tour. The mean of all the observations on the dew-point, from latitude $34^{\circ} 30'$ to latitude 32° on the Mississippi, was $40^{\circ}.1$, and the mean of all the dew-points, from latitude 37° to $34^{\circ}.30$, was $48^{\circ}.2$; thus the dew-point, at about latitude 32° , was found to be 8° lower than it was 3° further north.

The same phenomenon was shown in the Atlantic in going from Havana to New York. The dew-point gradually fell on leaving Havana, about latitude 23° , where it was at a mean on the 1st of May, $74^{\circ}.21$, to latitude 31° , where it was $58^{\circ}.12$; and yet the temperature of the water had sunk only one degree, from 79° to 78° , and the temperature of the air had sunk from 78° to 71° , at 8 P. M., at each place. The dew-point at Havana, at 8 P. M., was $5^{\circ}.12$ below the temperature of the water, and in latitude 31° the dew-point was $19^{\circ}.88$ below the temperature of the water. At Havana the dew-point was $4^{\circ}.12$ below the temperature of the air at 8 P. M., and at latitude 31° the dew-point was $12^{\circ}.88$ below the temperature of the air at the same hour.

On going north from this latitude, the dew-point gradually rose again till at latitude $34^{\circ}.40$ it was $67^{\circ}.52$, and then began to fall; and in latitude $35^{\circ}.20$ was $66^{\circ}.60$. It is true that we were now out of the Gulf Stream, the temperature of the water being but $61^{\circ}.5$ —that is, 11° lower than it was in latitude $34^{\circ}.40$, and the temperature of the air was $67^{\circ}.50$, $4^{\circ}.50$ lower than before.

It should be remarked, that at Havana the wind was N.E., and from latitude 30° to 31° it was E., and from 31° to $31^{\circ} 30'$ it was first E. by S., and then E.S.E., quite strong all the time, there being a great rain storm at the same time in the United States, as was afterwards ascertained. It is worthy of notice, that about the time the dew-point was lowest, the wind had just begun to have a little southing in it, showing that we were then getting beyond the borders of the trade winds. In crossing these borders we had no calms, but constantly strong easterly winds, gradually changing to S.E., where it continued, rather increasing in violence, with the dew-point constantly rising the further we went north, while we kept in the Gulf Stream; and, in latitude $34^{\circ} 40'$, just before we left the Gulf Stream, the dew-point was $9^{\circ}.40$ higher than it had been at latitude 31° , with a fall of temperature of one degree in the air, and a fall of five degrees in the water, at the same hour of the day, 4 P. M. of the 3d and 4th of May, 1851; and even when we had got fairly out of the Gulf Stream, three hours and a half afterwards, the dew point had sunk only one degree, though the water had sunk 11° from the last observation, and the air had sunk $4^{\circ}.5$. I had expected to find, in crossing these latitudes, not only the dew-point much lower than it was in adjacent latitudes, both north and south, but also very sudden changes in it.

This latter phenomenon I did not find in the Atlantic, probably because while crossing these latitudes there was no calm, but a constant strong wind from the east, blowing towards a great rain then existing in the United States. The books say that, in general, there is nearly a calm in these latitudes; and *I think it probable that subsequent observers, in passing the region of calms, will frequently meet with these sudden changes of the dew-point, produced by causes before explained.*

116. These sudden changes of the dew-point were frequently observed, with the air nearly calm, in going down the Mississippi, and during the eleven days I stopped at Carrollton, in from latitude 32° to 30° . For example: On the afternoon of the 15th May, at 5h. 30 min., the dew-point was $39^{\circ}.30$; wind very gentle, N.W.; and on the morning of the 16th it was calm, and the dew-point $53^{\circ}.50$ at 6h. 30 min.—that is, with but very little change of air, the dew-point had risen $13^{\circ}.20$; and then it fell during the morning, in 5h. 30 min., 8° , with the wind very gentle, W.S.W.

Again: At Carrollton the dew-point, on the afternoon of the 17th, was 50° , and on the

morning of the 18th, at $7\frac{1}{2}$ o'clock, it was $67^{\circ}.1$; calm all the time. Then, again, on the afternoon of the 21st, at $4\frac{1}{2}$ o'clock, the dew-point was $54^{\circ}.8$, with the wind very gentle W.N. W.; and next morning, the 22d, at 7 o'clock, the dew-point was down to $42^{\circ}.58$ —that is, a fall of more than 12° ; and at this moment it began to rain, and rained all day, (part of the time very hard,) with the dew-point rising in two hours to $46^{\circ}.2$, and the temperature of the air rising in the same time from 57° to 60° , so as to be still $13^{\circ}.8$ above the dew-point, after it had been raining a little for two hours. After two hours and a half more, (raining hard part of the time,) the dew-point was 52° , and the temperature of the air was $58^{\circ}.5$, a difference of $6^{\circ}.5$; and at 4 P. M., although it rained hard all the time, the dew-point was still 52° , and the temperature of the air had sunk to 54° . *To me it seems highly probable that there was a descending current of air on the outside of the borders of this rain, bringing with it a low dew-point, as before explained.*

Besides, the fact that it rained for several hours without raising the dew-point up to the temperature of the air, but rather bringing the temperature of the air down to approach the dew-point, is another proof, added to the many adduced in this report, that air in contact with water does not acquire a dew-point as high as the temperature of the water by several degrees.

Again, on the afternoon of the 27th, at 4 o'clock, the dew-point was 54° , with the wind very gentle west at Carrollton; and next morning, at 9 o'clock, the dew-point was $64^{\circ}.2$ ten miles below New Orleans, or about 14 miles from Carrollton.

These sudden variations of the dew-point I never observed in Philadelphia during calms, except just before or after a storm. I have since examined the very extensive journal of the dew-point kept at the Girard College, and find sudden changes of the dew-point only connected with storms, or sudden changes of the wind. This journal was kept by young men carefully instructed in the business by Prof. A. D. Bache, present Superintendent of the Coast Survey. And I think this phenomenon alone in the neighborhood of New Orleans, if it is a common occurrence there, as it was during the eleven days in which I made my experiments, is satisfactorily explained by the sinking down of the air from great heights to the surface of the earth in currents of no great width, and bringing with it a low dew-point at the moment of its descent. This explanation is rendered more satisfactory from the fact that I have since learned from an examination of the journals kept at Pensacola, New Orleans, and Natchez—namely: when these sudden depressions of the dew-point occur, there is generally a sudden rise of the barometer at the same time.

The following are given as examples:

On the 10th December, 1849, at New Orleans, the dew-point was 52° , barometer 29.94; and on the next day dew-point was 25° , barometer 30.33. At Pensacola at the same times the dew-points were $62^{\circ}.6$ and 27° , and barometer 30.00 and 30.35. At Nashville at the same times the dew-points were 24° and 16° , and the barometer 29.628 and 30.050.

At New Orleans on the 30th of December, 1849, at 3 P. M., the dew-point was $67^{\circ}.2$, barometer 29.93; and next morning at sunrise the dew-point was 25° , barometer 30.27. At Pensacola at the same times the dew-points were $61^{\circ}.5$ and 22.5 , and barometer 30.00 and 30.26. Same phenomena nearly at Natchez.

In November, 1849, no very remarkable sudden changes, either in the dew-point or barometer, took place either at Pensacola or New Orleans.

At New Orleans on the 13th of January, 1850, the dew-point was $61^{\circ}.3$, barometer 29.90; and the next day the dew-point was 36° , barometer 30.15. At Natchez at same times dew-point $58^{\circ}.5$ and 32° , barometer 29.924 and 30.150; and at Pensacola at the same times the dew-points were 57° and $26^{\circ}.5$, and barometer 30.00 and 30.20.

On the 21st, at 3 P. M., of the same month, at New Orleans the dew-point was 51° , barometer 29.70; and next morning the dew-point was 38° , barometer 30.05. At Pensacola at the same times the dew-points were $62^{\circ}.2$ and 34° , and barometer 29.80 and 30.10. In all these cases there was also a great depression of the thermometer, and some of them, though not all, seemed connected with rain.

Now, when it is considered that wherever the barometer stands above the mean, there should, or rather *must*, be a downward current of air; and whenever air descends from great heights to the surface of the earth, even though that upper air came from the equator to a high latitude before it descended, it brings a low dew-point with it; and as it is known that the barometer does generally stand higher in about the latitudes 29° to 34° than it does either north or south of that belt; and as, from all the facts which I have been able to collect on this subject, both from my own observation in my late tour, undertaken for this very purpose, and from those of others, it would appear that in this belt the dew-point is very low—many degrees lower than it is two or three degrees further north—and also very variable, sometimes falling more than fifteen degrees with but little wind, though generally with a rise of the barometer and a fall of temperature, and sometimes falling very rapidly with a south wind, which ought under any other circumstances to make the dew-point rise, it seems highly probable that these phenomena are connected together by a common cause, and that the hypothesis advanced here to explain these facts, which were predicted from the theory [No. 61] given in another part of this report to explain the high barometer in the outer border of the trade winds, is, to say the least, highly plausible. And if future observations should prove that in this belt generally, except where the trade winds are interrupted by monsoons, as in India, the dew-point is lower and the barometer higher than they are some degrees either north or south, then will the hypothesis become theory.

117. It is surely a curious fact, that I found the dew-point, at a mean of five experiments, in crossing from $30\frac{1}{2}^{\circ}$ to $31\frac{1}{2}^{\circ}$ north latitude in the Gulf Stream, $60^{\circ}.55$; while in crossing from $34\frac{1}{2}^{\circ}$ to 35° the dew-point was, at a mean of the experiments, $66^{\circ}.51$ —that is, 6° greater than it was 4° nearer the equator, and that, too, when the mean temperature of the ocean had sunk from 78° to 69° , and the temperature of the air from 73° to $70^{\circ}.8$. And the mean difference between the temperature of the air and the dew-point in the more southern latitude was $12^{\circ}.5$, and that of the more northern latitude was only $4^{\circ}.3$; and what is more remarkable still, the difference between the temperature of the surface of the sea and the dew-point in the more southern latitude was $17^{\circ}.5$, while in the more northern latitude the difference between the water and the dew-point was only $2^{\circ}.5$. It is true, no very sudden changes in the dew-point were observed in crossing these latitudes at sea, as there were on the land and in the Gulf of Mexico; but that does not prove that they do not occur.

The observations entire are given below. The dew-point is calculated from the following formula, which I formed many years ago by experiments instituted for the purpose: Let t = temperature of air, and t' = wet-bulb swung rapidly in the air, and t'' = temperature of

dew-point, then $t - \left(\frac{103 (t - t')}{t'} \right) = t''$ or the dew-point in degrees of Fahrenheit. *Moreover I have found that $300 (t - t'')$ is equal to the height of the bases of forming cumuli in feet; and this accords with the theory given above.**

118.—Table of dew-points in and on each side the northern extra-tropical zone of high barometer.

Date.	Hour.	Temp. of water.	Temperature of air.	Temp. of wet bulb.	Dew point.	Course of wind.	Upper clouds from.	Weather.	Latitude.	Longitude.	Remarks.
1851.		°	°	°	°				° /	° /	
May 10	5.30 p. m.		74	56	40.9	S.E. 1.	W.N.W. 1.	Clear	39 20	85 40	At Louisville, Ky.
11	7 a. m.		48	46	40.4	0.	0.	do.	39 00	86 00	Going down the Ohio.
	9 a. m.		56	48.5	40.5	N. 1.	0.	do.			
	11.40 a. m.		66	52	38.3	N. 1.		Hazy.			
	1.10 p. m.		68	54	41.3	N. 1.		do.			
	4.40 p. m.		72	55	40.2	N. 1.		do.			
	6.30 p. m.		68	53	38.85	N. 1.		do.			
12	7 a. m.		49.5	43	34	E. 1.		Cloudy	38 40	88 00	
	10.20 a. m.		54	46.5	37.4						
	2 p. m.		59	51	42.85			Little rain.			
	5 p. m.		58	53	48.1			Rain			
	6.15 p. m.		55	52	49			do.			Hard rain for two hours.
13	7 a. m.	54	56	55.5	55			do.			In the Mississippi, twenty miles below the mouth of the Ohio.
	10.15 a. m.	56	64	54	45	N.W. 3.		Clear.			
	4.15 p. m.	56.5	70	55	41.9			Cloudy			Rain at 6 p. m.
	6.50 p. m.		64	54	45	N.W. 5.		Rain			Very hard wind.
14	7.20 a. m.	56.2	53	46.25	38.4			Cloudy	34 40	90 30	Forty miles below Memphis.
	1 p. m.	58	55	48	40			do.			
	6.30 p. m.	58	56	50	43.7						
15	6.30 a. m.	58	50	46	41.05			Clear.			
	1.10 p. m.	60	61	50	38.34	N.W. 1/4.		do.			
	5.30 p. m.	61	65	52	39.3	N.W. 1/4.		do.	32 20	91 00	Seven miles below Vicksburg.
16	6.30 a. m.	62	54	53.25	52.50	0.		do.			Near Natchez.
	12 m.	63	71	57	45.56	S.W. 1.		do.	31 30	91 30	
	6 p. m.	64.2	73	60	50.7	Calm		do.			
17	6 a. m.	64	56	56	56	Fog		do.			No clouds.
	3.30 p. m.	65	74	60	50	N.N.W.		do.	30 20	90 10	At Carrollton, seven miles above New Orleans.
18	7.30 a. m.	65	68	67.5	67.1	0.		Fog.			Do.
19	4 p. m.	65	82	73.2	69			Clear.			Do.
20	7 a. m.	65	70	69.7	69.6	0.		Fog.			Do.
	6 p. m.		74	67.5	64.1	S.E. 2.	S.E.	Rain.			Do.
21	7 a. m.	64	62	57	52.9	N.N.W. 2.		Cloudy			Do.
	4.30 p. m.	64	74.5	62.5	54.8	W.N.W. 1.		do.			Do.
22	7 a. m.		57	50	42.58	E. 2.		Rain.			Do.
	9 a. m.		60	54.5	46.20	E. 2.		Little rain.			Do.
	11.30 a. m.		58	55	52	E. 1.		Hard rain.			Do.
	4 p. m.		54	53	52	E. 1/4.		do.			Do.
23	7 a. m.		62	61.5	61.2	E. 1/4.		Cloudy			
	12.2 p. m.		61	60	59.2	0.		Little rain.			
	3 p. m.		63.30	62	61.5	N. 1/4.		do.			
24	6.50 a. m.		62	61	60.3	E. 1/4.		Cloudy			
	9.15 a. m.		66	62	61.1	E. 2.	W. 1.	Clear.			
	12 m.	63	69.5	64	60.65	E. 1.	W. 1.				Thin clouds.
	4.30 p. m.	63	71	66	62.55	0.	W.S.W.	Cloudy			Rain at a distance.

* See my Philosophy of Storms, p. 167, where the accuracy of this rule is proved by sending up kites into the base of forming clouds and their height ascertained by trigonometry, and compared with the height as ascertained by the rule here given. See, also, page 547, where a plan is pointed out by means of the dew-point of the air breathed and the dew-point of the breath, which last I find to be 94° of Fahrenheit at all times, to ascertain the quantity of vapor formed in the lungs for any quantity of air inhaled and discharged. The principle is to subtract the quantity of vapor inspired with the air from the quantity found in the breath, and the remainder is the quantity formed in the lungs.

118.—Table of dew-points, &c.—Continued.

Date.	Hour.	Temp. of water.	Temperature of air.	Temp. of wet bulb.	Dew point.	Course of wind.	Upper clouds from.	Weather.	Latitude.	Longitude.	Remarks.
1851.		°	°	°	°				° /	° /	
May 25	7 a. m.	63	63	62	61.1	N.N.W. 2....		Clear.....			
	1 p. m.	63	72	64	59.1	N.N.W. 2....		do			
	3 p. m.		74	63	54.43	N.N.W. 2....		do			
26	8.30 a. m....	63	71	61	54.10	0.....		do			
	5 p. m.		78	63	53.18	0.....		do			
27	7 a. m.	62.75	62.5	62	61.75	0.....		do			
	11.15 a. m....		76	64	56.7	0.....		do			
	12.45 p. m....		80	65	56.2	W. ½.....	W. ½.....	do			
	4 p. m.		80.5	64	54	W. ½.....	W. ½.....	do			
Ap'l 28	9 a. m.		74	67.7	64.2	W. ½.....	W.N.W. 1....	do			Left New Orleans April 28 at 8 a. m.
	11 a. m.	63.5	74.5	67.5	64	0.....		do			
	1.30 p. m....		83	71.6	68	0.....		do			
	2.40 p. m....	66	80	68	61.85	S.W. 1.....		do			
	3.30 p. m....		80.5	68	61.58	S.W. 2.....		do	29 00	89 30	Passing light-house.
	5.45 p. m....		76	68	63.88	S. 2.....		do	28 48	89 10	
	6.40 p. m....	76	73	67	63.78	S. 2.....		do	28 42	88 24	In Gulf of Mexico.
	8.30 p. m....	73	72	68	65.94	S. 2.....		do	28 30	88 00	
	9 p. m.	73	72	68	65.94						
	9.30 p. m....	73	72	68	65.94						
	10 p. m.	73	72	68	65.94						
	10.30 p. m....	73	72	69	67.50						
	11 p. m.	73	72	69	67.50						
	11.30 p. m....	73	72	69	67.50						
	12 p. m.	74	73	69	67						
29	12.30 a. m....	74	75	68	64.40						
	1 a. m.	74	76	66	60						Observations made by the officers of the steamer Falcon, from latitude 28° 30' to 27° 30'.
	1.30 a. m....	77	76	65	58.57						
	2 a. m.	77	75	66	60.96						
	2.30 a. m....	78	75	67	62.70						
	3 a. m.	79	75	66	60.95						
	3.30 a. m....	79	75	66	60.95						
	4 a. m.	78	75	66	62.70						
	4.30 a. m....	76	74	66	61.50						
	5 a. m.	74	72	64	59.12						
	6 a. m.	78	74.5	65	59.5	E. ½.....		Clear.....	27 20	87 30	
	7.45 a. m....	78	77	67	61.6	E. by S. 1....	N.W. 2....	do			
	8.45 a. m....	78.25	76	66	60.4	E. by S. 1....		do			
	9.20 a. m....		77	66	61.4	E. 2.....		do			
	10.30 a. m....		77	68	62.37	E. 2.....		do			
	11.15 a. m....	78.5	76	68	63.88	E. 3.....		do			
	2 p. m.	78.75	77	70	66.7	S.E. 3.....		do	27 00	85 55	
	3.30 p. m....	78	76	60	67.14	S.E. 3.....		do			
	6 p. m.		76	69	65.55	S.E. 3.....		do			
	8.30 p. m....	77	76	71	68.75						
	9 p. m.	77	76	71	68.75						
	9.30 p. m....	77	75	70	67.80						
	10 p. m.	77	75	70	67.80						
	10.30 p. m....	77	75	70	67.80						
	11 p. m.	77	75	70	67.80						
	11.30 p. m....	76	75	69	66.10						
	12 p. m.	76	75	70	67.80						
30	12.30 a. m....	76	75	70	67.80						Observations made by the officers of the steamer Falcon, from latitude 25° 50' to 24° 50'.
	1 a. m.	77	74	71	69.65						
	1.30 a. m....	76	73	70	68.59						
	2 a. m.	76	74	70	68.10						
	2.30 a. m....	76	74	70	68.10						
	3 a. m.	76	73	71	70.10						
	3.30 a. m....	75	73	71	70.10						
		75	74	71	69.65						

118.—Table of dew-points, &c.—Continued.

Date.	Hour.	Temp. of water.	Temperature of air.	Temp. of wet bulb.	Dew-point.	Course of wind.	Upper clouds from.	Weather.	Latitude.	Longitude.	Remarks.
1851.		°	°	°	°				° /	° /	
Ap'l 30	6 a. m.	75	75	71.2	69.5	S.E. 3. ....	.....	Clear.....	24 50	84 00	
	9.30 a. m.	75	76	73	71.77	S.E. 2. ....	.....	do. ....	.....	.....	
	12 a. m.	77	77.5	73	71.5	S.E. 3. ....	.....	do. ....	.....	.....	
	4 p. m.	77.5	77.5	73.5	71.9	N.E. 1. ....	.....	do.	23 50	83 00	
	9 p. m.	76	77	75	74.26						
	10 p. m.	76	77	75	74.26						
	11 p. m.	76	77	75	74.26						
	12 p. m.	77	78	76	75.29						
May 1	12.30 a. m.	77	77	74	72.83						
	1 a. m.	78	78	74	72.42						
	1.30 a. m.	79	78	75	73.90						Observations by the officers of the steamer Falcon, from lat- itude 23° 50' to 23° 9'.
	2.10 a. m.	79	78	75	73.90						
	2.30 a. m.	79	78	74	72.42						
	3 a. m.	79	78	74.5	73.15						
	3.30 a. m.	79	78	73	70.95						
	4 a. m.	79	77	72	69.85						
	5 a. m.	79	76	74	73.21						
	8 a. m.	79	77	74.5	73.5	N.E. 1. ....	.....		23 09	82 19	At Havana.
	4.45 p. m.	79	83.5	78	75.25	N.E. 1.	N.E. 1.				Leaving Havana.
	8 p. m.	79	78	75	73.88	N. 1. ....	.....				
2	6 a. m.	79	77	74.5	73.5	N.W.	S. by W.		25 10	80 20	
	10 a. m.	76.5	76	71	68.7	N.	S. by W.				
	12.30 p. m.	76.25	76.25	71.25	69	N.N.E. 2. ....	.....				
	8 p. m.	76	75	67.75	64	N.N.E. 4. ....	.....		27 00		
3	8.30 a. m.		74	68.75	66.14	E. 4. ....	.....				
	11 a. m.		73	65.75	61.66	E. 4. ....	.....		30 38	79 03	
	12 m.	78	74	67	60.17	E. 4. ....	.....				
	1 p. m.		73	65.75	61.65	E. 4. ....	.....				
	4 p. m.		73	66	61.70	E. by S. 5. ....	.....				
	7 p. m.		71	64	58.12	E.S.E. 6. ....	.....		31 50	78 50	
4	5.30 a. m.		70	66	63.76	S.E. 3. ....	.....				
	7 a. m.	72	71	65.5	62.35	S.E. 3. ....	.....				
	9.30 a. m.	72	73	67	63.78	S.E. 3. ....	.....				
	10.30 a. m.	72.5	72	66	62.73	S.E. 3. ....	.....				
	12 a. m.		71	66	63.20	S.E. 3.	W.N.W.				
	2.30 a. m.	73	73	68	65.42	S.E. 4.	W.N.W.				
	4 a. m.	72.5	72	69	67.52	S.E. 4.	W.N.W.		34 40	75 10	
	7.30 a. m.	61.5	67.5	67	66.60	S. by W. ....	.....		35 10	75 00	

119. That the evolution of latent caloric during the formation of great clouds is not only a *vera causa*, but a sufficient cause of low barometer under the cloud, without calling in the hypothetical aid of electricity,* is demonstrated by the experiments given, with their results, in

* Besides the reasons given in No. 75, why a convective discharge of electricity cannot be the cause of the up-moving column of air, and the fall of the barometer in hurricanes, the following reasons are worth consideration :

On this supposition the weight of all bodies at the surface of the earth during the passage of a hurricane would be diminished, and among them the weight of the pendulum of the clock. This would cause the clock to go slower than at other times, which, so far as I know, has never been observed to be the case.

Again, even if the upper air from its great rarefaction could act as a conducting plate, and the lower air as an electric, the tops of the high mountains would either penetrate the upper plate, and by their conducting power prevent any accumulation of electricity, or, at least, by their near approach to the upper plate, cause all discharges between the two plates, whether the discharges are disruptive or convective, to take place there; and yet it is known that no tornadoes nor hurricanes take place on high mountains, and that even on crossing hills of moderate height they become less violent than they are in the hollows where the dew-point is higher, it may be safely inferred that electricity is not the cause of tornadoes and hurricanes.

this report; and besides, if any one will make the calculation, or accompany me in the following remarks, he will perceive that the same conclusion may be drawn from the acknowledged laws of the specific caloric of air, 0.267, the latent caloric of steam or aqueous vapor in the atmosphere, 1210°, at the temperature of 32°, and its specific gravity 0.625, that of air at the same temperature and pressure being unity. Now, if we suppose the dew-point 32° at Cape Horn, at which temperature the tension of the vapor is 0.200 inch, the quantity of vapor in the lower air will be $\frac{1}{240}$ of its weight, for $\frac{5}{8}$ of 0.200 of $\frac{1}{30}$ is $\frac{1}{240}$; and if one portion of vapor in weight be condensed in 240 portions of water at the temperature of 32°, it will heat the water about 5°.05; and if 5°.05 be divided by 0.267, the specific caloric of air, it will give 18°.9, the number of degrees that air would be heated at the temperature of 32° by having all the vapor in it condensed when its dew-point is 32°.

Here we have a column of air rising with a temperature of, say 37° at the surface of the sea, gradually acquiring a higher temperature than the surrounding air at the same height as it ascends; and finally, when it has condensed all its vapor by the cold of expansion from diminished pressure, which it will have done nearly when it has risen high enough to expand into double the space, beyond which it goes up to the top of the atmosphere, with a temperature constantly 18°.9 warmer than the surrounding atmosphere through which it passes.†

If we suppose the mean temperature of the whole air, in these southern and northern belts of low barometer, from the surface of the sea to the surface of the atmosphere, to be 48° below zero, which it is very nearly by my experiments, and the temperature of the whole column of ascending air to be 12° warmer than the air on the outside, then will it be $\frac{1.2}{41.2}$ lighter; and if we suppose it were all to spread out in the upper regions, without swelling upwards, so as to stand no higher at the surface of the up-moving column than in the surrounding regions, then would the barometer fall at the foot of this ascending column $\frac{1.2}{41.2}$ of 30 inches, that is, 1.144 inch. But the air *would* swell up and stand above the level of surrounding regions, at the top of the up-moving column, and on this account the barometer would not fall as much as the calculation above indicates.

Yet, if we suppose only two-thirds to spread out above beyond the borders of the up-moving column, (which is a very moderate allowance,) the barometer would still sink two-thirds of 1.144 inch = 0.762.

120. If the condensed vapor should congeal and fall in the form of snow, 140 degrees of caloric of fluidity would be evolved in addition, and this would cause the fall of the barometer to be greater by $\frac{1.40}{1210}$ of 0.762 inch = 0.088 inch; and this, added to 0.762, makes 0.850 inch, which is the amount that the barometer would fall according to the assumed circumstances. If we had supposed a case where the dew-point was higher, the fall of the barometer would be greater; and if we had assumed a dew-point lower, the fall of the barometer would be less. In either case, the calculation of the amount could be made on the same principles.

In the above calculation, no allowance is made for the greater specific caloric of the air at great altitudes, where the density is much diminished by diminished pressure, nor is any notice taken of the diminished density of the air in the up-moving column, in consequence of the higher dew-point in the cloud, both on account of its higher temperature and more complete saturation with vapor than on the outside. Nor is any notice taken of the fact that, as the

† Experiments with the double nephoscope make the temperature 20° warmer instead of 18°.9. (See No. 143.)

temperature sunk in the up-moving column, the latent caloric of the vapor became greater ; but if a calculation should be made allowing for all these three, it would be found that the two last would increase the fall of the barometer, while the first would diminish it, and the correction would leave the result nearly as calculated. There is another correction, however, which ought not to be neglected, and that is the weight of the condensed vapor, which may be said to press with its whole weight on the ascending column. Now this weight is $\frac{1}{8}$ of 0.200 of an inch of mercury—that is, 0.125 inch ; and this latter quantity subtracted from 0.850, leaves 0.725 inch for the corrected depression of the barometer, where the dew-point is 32° , and the condensed vapor falls in snow. If the condensed vapor falls in rain, the depression would only be 0.637 inch.

121. There is one important datum assumed in the above calculation, namely, that if a column of dry air were to ascend in the atmosphere in its normal state as to temperature, it would retain at its different heights the same relative temperature with the surrounding air that it had at the start, or cool by expansion from diminishing pressure just as fast as the atmosphere itself cools at different heights ; that is, about seventy-six degrees for an elevation where the air would expand into double the space when the air is about 76° in temperature at the surface of the earth.

For the correctness of this principle I assign the following reasons : First. This is the degree of cold produced in dry air, by expanding into double volume from diminished pressure at the temperature of 76° , as proved by my experiments with the double nephelescope.* Second. Gay Lussac, in his celebrated balloon ascent to where the air was accurately one-half the density as the air below, found the temperature had sunk $72^{\circ}.5$ Fahrenheit, which is a little less than the quantity here assumed. But Kaemtz gives a great many simultaneous observations made at Halle, and at the Brocken, 1,140 metres above Halle, where the decrease of temperature was sometimes as great as $11^{\circ}.70$ between those two places. And he says, everything else being equal, rain is much more probable when the decrease of temperature with the height is more rapid. He says :

“The observations made in the Alps justify the law of more rapid decrease of temperature during rain. The same facts have been established by the French commission in the very high latitudes of Europe, on the Tyvefield, latitude $70^{\circ} 37'$, height 418 metres ; and on the Sloadberg, at Spitzbergen, latitude $77^{\circ} 30'$, height 560 metres. The observations made at Bosekop by means of kites and captive balloons no less clearly indicate the same result.”

And he gives a most striking illustration of the principle before explained, which I had not seen when I wrote the explanation of clouds not forming when the air near the ground is colder than the air above. He says :

“In 1838, during the months of January and February, the air at Halle was constantly saturated with the vapor of water, and yet there was not a cloud over the sky ; but in this case, the lower strata were so cooled by radiation that, on the Brocken, 1,140 metres above Halle, the thermometer was sometimes 10° centigrade higher than at Halle.”

But on this point a most conclusive observation was made by MM. Barral and Bixio, in their balloon ascent from Paris, on the afternoon of the 27th July, 1851. They found the temperature sink from $10^{\circ}.5$ below zero centigrade to 35° below, in ascending from 6,330 metres high to 6,512 metres ; that is, $24^{\circ}.5$ centigrade in going up 182 metres, which is a fall of $44^{\circ}.1$

Fahrenheit for 199 yards elevation. The first of these temperatures was taken in the cloud, (for there had been a violent rain about an hour and a quarter before the ascent;) and the second outside of the cloud, as Arago says in his account of this ascent, in the *Annuaire Meteorologique de la France* for 1851, page 306. On going up still further, to the height of 7,016 metres, the thermometer sunk to 39° below zero centigrade.

While they were in the cloud, the thermometer was at $10^{\circ}.3$ at the height of 1,480 metres, and on ascending to the height of 6,330 metres, the temperature was $10^{\circ}.5$ below zero; that is, $20^{\circ}.8$ centigrade for an elevation in the cloud of 4,847 metres; that is, 37° Fahrenheit for 5,300 yards of elevation; whereas, in leaving the cloud only 199 yards, the temperature fell $44^{\circ}.1$ Fahrenheit below what it was in the cloud. Arago takes pains to show that there was no error in the observations, however incredible they may appear to be.

122. From these observations and experiments alone, I am justified in using in my calculations the datum, *that equal weights of air at all heights in the normal state contain equal quantities of caloric nearly*. But the same principle may be inferred from the laws of the equilibrium of air, without any experiments but those which nature herself makes, and that, too, without founding the argument on my theory. First, it is a fact that a great quantity of aqueous vapor is condensed *by some means* every year in the air, between one-half of a mile and ten miles high—enough in England to heat the air by the latent caloric evolved more than 200° , and in the United States more than 400° , and in some parts of India more than 3,000; for in each inch of rain the caloric evolved is sufficient to heat the air to the top of the atmosphere ten degrees. Now, this air, so heated, will never descend to the surface of the earth through air colder than itself; therefore, it must radiate its heat away into space, or otherwise its temperature would soon be as great as that of red-hot iron. But this is not the case. Air, therefore, having received the latent caloric evolved in storms, radiates its heat away, and remains constantly much colder at great heights than it is below. As soon, however, after a storm, in which it receives much caloric, evolved by the condensation of the vapors, as it radiates all its superabundant caloric, and begins to have less caloric in it for equal weights than the air below, then the warmer air below will begin to form up-moving currents through the colder and specifically heavier air into which it penetrates, and the colder air all around will subside. Now, this air which moves up will carry its caloric with it, and, as long as it is warmer than the air around it on the same horizontal level, it will continue to ascend. And if the air had no vapor in it to condense, there would be formed every day up-moving columns from below, and down-moving currents from above; for the air at the surface of the earth becoming a little above the mean in temperature every day, up-moving columns would be formed, and, becoming a little below the mean every night, the up-moving currents would cease: thus there would always be very little difference in the quantity of caloric contained in equal weights of the air above and below. During the hottest part of the day the air below would contain a little more caloric than the air above, and during the coldest part of the night it would contain a little less. It is true, that during the night the air above would contain less caloric than in the day, but not so much less as the air below; because the earth being, as is known, a better radiator than the air, it cools the air in contact with it during the night more than the air above cools by its own radiation. This difference would never amount to more than a few degrees, if the air had no vapor in it; but, as it has vapor, and as, in storms, that vapor is condensed and gives out its

latent caloric, it is manifest that, if the air before this condensation contained a normal quantity of caloric, it must contain much more after the condensation; and, though it now begins to radiate its caloric much more rapidly, in consequence of its higher temperature, it will be some time, perhaps several days, before it is cooled down to a mean.

123. Here my theory naturally and inevitably comes in; for, if the small increase of temperature during the day at the surface of the earth causes up-moving columns, which, in the normal state of the air, would not come to equilibrium till they reached the surface of the atmosphere, *a fortiori*, when these columns, in their upward motion, received the caloric evolved from the condensed vapor, their upward force will be increased proportionately; and they certainly will go up and spread themselves out at the surface of the atmosphere, and remain there until they are cooled down by radiation a little below the normal temperature, when other up-moving columns will take their place. Among the many excellencies and beauties of this contrivance is the complete change of the lower parts of the atmosphere to the upper, and of the upper to the lower. Hence the common saying, "a thunder storm purifies the air."

124. M. Pouillet has shown, I think satisfactorily, that, from the nature of the atmosphere which he calls a diathermanous envelope, the lower stratum of it would be warmer than the upper, merely from the absorption and retention of the heat from the stars, without the action of the sun; and he says: "The decrease of temperature in the atmosphere is not *at all* due to the ascending and descending currents which the action of the sun may cause near the earth's surface."

125. Now, I grant that if there were no ascending and descending currents, the temperature of the atmosphere would decrease all the way to the top from the surface of the earth; but it by no means follows that the amount of decrease would be the same that it is with the ascending and descending currents which actually take place: and however widely the two causes might differ in their effects, it is manifest that the law of cooling in the atmosphere will correspond nearly with the law of cooling of air by expansion from diminished pressure. Hence it follows that if any two portions of air, in a region where it has remained clear for several days—one near the surface of the earth, and the other at any height over it—should be made to approach each other without losing or acquiring any caloric on their passage, they would on meeting have nearly the same temperature, and also be of nearly the same temperature as the air where they met, whether the place of meeting should be high or low in the atmosphere.

126. M. Pouillet says, also, (Scientific Memoirs, November, 1844,) "that M. Poisson, in his last work, has shown that the upper strata of the atmosphere must necessarily be at a much lower temperature than the temperature of space. He has deduced this result, on the one hand, from the numbers at which he has arrived to express the temperature of space; and on the other, from the mechanical conditions of equilibrium, which could not be fulfilled at the limits of the atmosphere if the air did not there experience a degree of cold sufficient to make it lose all elasticity."

This consequence, which might appear extraordinary, says M. Pouillet, when presented only as a mechanical necessity, may, perhaps, now appear, if not more certain, at least more natural, since it results from the laws of radiant heat, and since it is by this explained and referred to its real origin."

If the temperature of space is not more than 50° or 60° centigrade below the freezing point,

there is no doubt that the upper stratum of the atmosphere is much below the temperature of space; and, moreover, it will follow also that the upper air, on that supposition, radiates more caloric than it receives from both warmer space above and warmer atmosphere and earth below—for the air in the upper region *does* become colder by radiation after it has received the latent caloric of the vapor condensed in a storm-cloud; otherwise up-moving columns and storms would cease, as before explained. But if the temperature of space is as low as 142° centigrade below the freezing point, which M. Pouillet makes it, then is it colder than the upper atmosphere at its coldest point. [No. 141.]

It is painful to me to come to a different conclusion on this subject from these great men; but my experiments show that air loses its elasticity by expansion, and not merely by diminished temperature; and, indeed, that the ultimate temperature, at the moment it ceases to expand by taking off all pressure, it is quite different, according to the temperature it had before the pressure was removed.

When a column of air ascends in a storm to the top of the atmosphere, it will cease to expand whenever the uppermost particles are so far from those next below them that the repulsion between them is exactly equal to the gravitation of the uppermost particles to the earth—and this must take place somewhere; for as the air expands in going upwards, the repulsion diminishes much more rapidly than the gravitation towards the earth diminishes; therefore, these forces will become equal somewhere, whether the temperature is high or low at the surface of the earth.

So far, however, as my theory of rain is concerned, I feel no interest in establishing the views here advanced concerning the temperature of space. If the upper air can radiate its superabundant caloric after a storm into space warmer than itself, be it so. It is enough for my theory to prove that it *does* radiate its caloric; and I think *that* has been most satisfactorily done.

I may add, however, that I feel less hesitation in differing with these great men on this point, as they differ so much among themselves. Poisson makes the temperature of space about 32° Fahrenheit—that is, about at the freezing point; Fourier makes it about 90° below the freezing point; and Pouillet makes it about 222° below the freezing point. I have given my reasons before why I think M. Pouillet is nearly correct.

127. Before introducing my experiments with the double nephelescope, it is proper to indicate the mode of calculating the results, both when dry air was used and when moist air was used.

To find cold produced in dry air.—Subtract height of mercury in nephelescope after equilibrium of temperature from barometer, and call the remainder p' ; then say, $p' : 448 + t :: d : \text{cold}$; (d) is the change of height of mercury after explosion; (t) is the temperature.

To prove the work, subtract the cold thus found from $448 + t$, and call the remainder t' , and also d from p' , and then say: $(p' - d) : t' :: d : h$; (h) is the number of degrees heated after explosion in coming to equilibrium of temperature, which ought, if the work is right, to equal the cold produced by expansion.

128. *To find expansion of dry air.*—Divide mercury in nephelescope after explosion and equilibrium of temperature by barometer; or divide the quantity of air going out of nephelescope in explosion by the quantity of air in nephelescope before explosion, and the quotient will be the expansion in all cases, according to this last form of the rule.

129. *To find expansion in moist air.*—Add the quantity (v) of vapor condensed to the mercury in nephelescope after explosion and equilibrium of temperature, and divide the sum by barometer.

130. *To find cold in moist air.*—Add the quantity (v') of vapor generated during the rise of temperature to the mercury in nephelescope after equilibrium of temperature, subtract the sum from barometer, and call the remainder p' ; subtract also v' from d , and then say—

$$p' : (448 + t) :: (d - v') : c = \text{cold produced.}$$

Note.—(v) and (v') must be found by trial.

131. *To find cold in moist air.*—Example: On February 11, 1850, the barometer was 30.04, and the thermometer 50° . The height of nephelescope after explosion and equilibrium of temperature, 14.656 inches; an expansion was made of 0.4980, and the rise of mercury after explosion, including the force of vapor generated during rise, was 1.569 inch. What was the cold produced by expansion? The cold of dry air for such expansion is $74^{\circ}.50$; and I have observed that when the temperature of the air and the dew-point are about 50° , the cold produced in moist air for an expansion into double the space is about two-thirds of that in dry air. Let us, then, suppose that the temperature in this case sunk 44° ; that is, down to the temperature of 6° . The force of vapor at this temperature is 0.0770. Subtract 0.077 from 0.3734, the force of vapor at 50° , and it leaves 0.2964 inch, which is the quantity of vapor generated during the rise of temperature after explosion. Subtract, then, 0.2964 from 1.569, the whole rise, and it leaves 1.273 (d) for the rise due to the expansion of air alone from the heat that went into the air after explosion.

We are now prepared to calculate the cold according to the rule laid down before for dry air. The height of mercury in nephelescope after equilibrium of temperature was, as above, 14.656 inches; to this add 0.2964 for the quantity that was due to the generation of vapor, it makes 14.952; and this last number being subtracted from the barometer 30.04, leaves 15.088 for the quantity of air in nephelescope after explosion (p' .) The formula then is—

(p')	(t)	(d)	(c)
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15.088 : $448 + 50 :: 1.273 : 42^{\circ}.01$. The degree of cold, then, turns out, by calculation, less than our supposition of 44° . When the result of calculation is less than the supposition, the supposition was too great, and the true degree of cold produced is between the supposition and the result, but much nearer to the result than to the supposition. If, now, we make a new supposition that the cold was $42^{\circ}.2$, and work out a new result in the same manner, we will find that the result and our supposition will nearly agree, and that $42^{\circ}.2$ is nearly the true degree of cold produced in the above experiment, on supposition that vapor is generated up to complete saturation during the rise of temperature in nephelescope after explosion; but the experiments detailed render it nearly certain that this is not the case.

132. When I commenced these experiments I expected that I should be able to ascertain nearly the specific caloric of air under different pressures; but when I had calculated its amount in a great many cases, in the manner hereafter explained, I found, to my astonishment, that the results oscillated a little above and below 0.1800 for pressures both above and below atmospheric pressure. These calculations were made on the supposition that, because the air was in contact with water, the dew-point in the nephelescope, both at the beginning and end of the experiment, was the same as the temperature of the air in it. This I was justified in supposing from the acknowledged doctrine that air in contact with water soon has the dew-point the same as its own temperature.

133. The specific caloric of air, resulting from this supposition, being so much less than was

expected, and especially the result that the specific caloric of air at different densities was about the same, induced me to vary my experiment in such a way as to test the principle whether the specific caloric of air would turn out the same, when I knew the dew-point exactly in the nephelescope, both at the beginning and end of the experiment. For this purpose I used the nephelescope *dry* in the inside, and ascertained the dew-point of the air with which it was charged, by means of a tin cup with water in it, cooled down by artificial means till the moisture in the air condensed on the outside of it, care being taken to ascertain, by a standard thermometer thrust in it, the *highest* temperature at which the vapor would condense on it. By this method the specific caloric of air at half the mean density turned out to be 0.2837, and at mean density 0.2188.

134. This result still differs considerably from 0.2670, which is generally acknowledged to be the true specific caloric of air at mean density. I do not bring forward these experiments as a proof that the acknowledged number, 0.2670, is incorrect; because the tables of dew-points, and those of latent caloric of steam and of water, and of the expansion of air from heat, on which my experiments and calculations are founded, may be erroneous to a considerable amount. Indeed, according to late and very careful experiments of Regnault and others, the table of dew-points differs from Biot's, which I used; and the latent caloric of water is 142, instead of 140; and the co-efficient of the expansion of air from heat is 493, instead of 480, varying a little with the density; nor is the sum of the latent and sensible caloric of steam or vapor a constant quantity. Yet if I had adopted all these late results in my calculations, the specific caloric of air would have come out nearly the same as with the data which I used.

135. It is not at all wonderful that the specific caloric of air should come out too little when it is calculated on the supposition that the air in the nephelescope became saturated by evaporation from the water within it, while the temperature was rising to equilibrium after explosion, because *such is not the fact*; but it is very remarkable, and well worthy of future investigation, how the specific caloric of air turned out to be considerably less than 0.2670, the received number, when the experiments were made with a known dew-point both at the beginning and end. This result is the more remarkable, when it is considered that there is one correction not taken into account, which, if it had been introduced, would have brought out the specific caloric of air still less. It is a correction, the amount of which, in the present state of science, cannot be exactly known; yet the following consideration will suffice to show that it is something, though very small.

136. It is certain that, during the very brief time that elapsed while the explosion of the air in the nephelescope was going on, the air, as it became colder and colder, would be receiving heat from contact with the sides of the nephelescope; and the quantity thus received would be greater in the case of dry air than in moist, because of the greater cold produced in the former than in the latter. Now, whatever this difference may be, when no allowance is made for it, it would bring out a greater specific caloric of air than if the allowance should be made. The length of time of the explosion may be safely stated to be between one-fiftieth and one-hundredth of the whole time required to produce equilibrium of temperature after explosion; and therefore the heat received during explosion is between one and two per cent. of the whole, and in quantity about half as great in moist air as in dry—sometimes a little more and sometimes a little less.

137. As the method here employed to ascertain the specific caloric of air at different densities

is entirely new, and, therefore, not without interest, it is proper to explain the mode of making the calculation of it from the experiments :

First. Find the quantity of vapor uncondensed, by taking the force of the vapor in the nephelescope at the lowest temperature, and multiplying it by the quotient of the arithmetical complement of the expansion into the barometric column : or, in other words, subtract the nephelescopic column of mercury, after equilibrium of temperature, from the barometric column, and divide barometer by remainder ; then take the quotient and multiply by it the force of vapor at the lowest temperature, and it will give the force of vapor uncondensed.

Second. Subtract this quantity uncondensed from the quantity in the nephelescope before explosion, and it will give the quantity of vapor condensed.

Third. Divide the barometric column, minus the force of vapor at the highest dew-point, by five-eighths of the force of vapor condensed, and the quotient will be the *weight* of the vapor condensed, proportional to that of the air. That is, the quotient will show how many times the weight of the air is greater than the weight of the vapor contained in it. Divide by this quotient, or proportional weight of vapor, its latent caloric, which is found by subtracting the lowest temperature to which the air was reduced from 1242, and, if that lowest temperature was below 32° , by adding to the remainder 140 for the caloric of fluidity, the quotient will be the number of degrees that an equal weight of water would be heated by the condensed vapor. Divide this quotient by the number of degrees that the air was hindered from cooling, as compared with dry air for an equal expansion, and the quotient is the *specific caloric of air* at the temperature and pressure of the experiment.

When partially moist air was used, the dew-point in the nephelescope was ascertained by adding the quantity of vapor pumped in to the quantity in the air.

138. It is proper to add, that the reason why the specific caloric of air at half common density came out nearly the same (0.1800) as the specific caloric at common density, when it was calculated on the supposition that air in contact with water has the dew-point the same as the temperature of the air, is, that this supposition gives a much greater error in the case of rarefied air than in air of common density, as will be understood by any one who shall take the trouble to think on the subject, without any further explanation here.

139. If any one shall repeat these experiments, he will find it necessary, as a preliminary, to educate both his ear and his fingers by repeated trials, so as to be able to close the stop-cock at the instant he ceases to hear the hissing sound produced by the escaping air. Without accuracy in this particular, the experiments will be so discrepant as to inspire but little confidence in the results.

The experiments themselves are given in the following tables. The careful reader will thus have an opportunity of comparing with them the general laws which I have drawn from them, and perhaps he will be able to deduce other laws from them which have escaped my notice.

Table of experiments with double nephoscope—dry common air.

Date.	Temperature, Fahrenheit.	Barometer.	Height of mercury in Neph. immediately after explosion.	Height of mercury in Neph. after equilibrium of temperature.	Difference of two last, or change of height from change of temperature.	Cold produced by expansion.	Expansion or quotient of quantity of air discharged by quantity in Neph. before discharge.	Quot't of 7th divided by 8th.	Experiments.	No. of degrees of cold for one inch of mercury disch'd, or 7th divided by 5th.	Degrees of cold produced for one inch fall of barometer, or 7th divided by 4th.
1	2	3	4	5	6	7	8	9	10	11	12
1850.											
Feb. 5	32°	30.68	17.548	15.156	2.392	69.02	.4940	1397	Mean of 5 experiments.	4.555	3.935
6	36	30.74	23.0113	21.049	1.9623	97.17	.6847	1419	Mean of 7 experiments.	4.616	4.223
6	36	30.68	17.5933	15.36	2.233	70.26	.5006	1403	Mean of 3 experiments.	4.574	3.994
5 & 6	34	30.68	17.5706	15.258	2.3126	69.64	.4973	1400	Mean of 8 experiments.	4.566	3.963
7	63	30.47	24.40	22.666	1.7333	113.55	.7442	1525	Mean of 3 experiments.	5.000	4.653
7	66	30.44	22.216	20.148	2.068	103.28	.6318	1560	Mean of 5 experiments.	5.126	4.649
8	62	30.25	17.3733	15.18	2.1933	74.227	.5018	1477	Mean of 3 experiments.	4.889	4.272
8	67.5	30.20	22.09	20.09	2.00	102.18	.6652	1536	Mean of 2 experiments.	5.085	4.625
9	69.5	29.58	21.7766	19.8066	1.97	105.61	.6699	1576	Mean of 3 experiments.	5.332	4.850
9	69.5	29.52	17.086	14.904	2.188	77.204	.5048	1529	Mean of 5 experiments.	5.183	4.519
11	50	30.00	17.2233	15.04833	2.175	72.24	.5016	1460	Mean of 6 experiments.	4.800	4.195
11	56	30.02	22.333	20.10	2.23	113.32	.6695	1692	Mean of 6 experiments.	5.639	5.074
11	56	30.03	17.385	14.97	2.415	80.82	.4985	1621	Mean of 4 experiments.	5.398	4.650
12	65.5	30.30	12.31	10.21	2.10	53.67	.3369	1593	Mean of 4 experiments.	5.256	4.360
12	69	30.30	17.468	15.092	2.376	80.76	.4981	1621	Mean of 4 experiments.	5.351	4.623
12	69.5	30.30	22.433	20.2066	2.2266	114.36	.6666	1716	Mean of 3 experiments.	5.660	5.098
13	73.5	30.23	22.32	20.118	2.202	113.56	.6655	1666	Mean of 5 experiments.	5.644	5.086
15	67	29.49	16.996	14.728	2.268	79.12	.4994	1594	Mean of 6 experiments.	5.373	4.655
15	67	29.52	21.725	19.625	2.10	108.38	.6630	1645	Mean of 3 experiments.	5.524	4.990
15	67.8	29.56	11.8633	9.8733	1.99	52.13	.3340	1560	Mean of 6 experiments.	5.279	4.395
16	51	30.13	17.395	15.1033	2.2916	74.52	.5012	1487	Mean of 3 experiments.	4.935	4.284
16	51	30.13	22.1266	20.12	2.0066	100.29	.6677	1502	Mean of 3 experiments.	4.979	4.534
16	51	30.12	24.252	22.432	1.820	118.15	.7447	1584	Mean of 5 experiments.	5.274	4.866

Table of experiments—dry common air—Continued.

Date.	Thermometer.	Barometer.	Height of mercury before explosion.	Height of mercury after explosion.	Difference of two last, or change for change of temperature.	Cold produced by expansion.	Expansion.	Quotient of 7th divided by 8th.	Experiments.	No. of degrees of cold for one inch disch'd.	No. of degrees of cold for one inch fall of barometer.
1	2	3	4	5	6	7	8	9	10	11	12
1850.											
Feb. 18	62°	29.750	11.88	9.892	1.988	50.926	.3325	1531	Mean of 5 experiments.	5.146	4.287
18	62	29.73	12.67	10.67	2.00	53.51	.3588	1491	Mean of 2 experiments.	5.015	4.223
18	62	29.70	14.92	12.80	2.12	63.98	.4309	1485	Mean of 2 experiments.	4.998	4.288
18	62	29.68	17.10	14.866	2.233	76.67	.5071	1512	Mean of 3 experiments.	5.157	4.483
18	62	29.65	19.18	16.96	2.22	89.22	.5720	1559	Mean of 3 experiments.	5.260	4.652
18	62	29.64	21.7866	19.88	1.9066	99.63	.6707	1485	Mean of 3 experiments.	5.011	4.572
18	62	29.60	23.822	22.164	1.658	113.71	.7487	1523	Mean of 5 experiments.	5.130	4.773
14	72.5	29.30	16.75	14.60	2.15	76.02	.4986	1524	.....	5.206	4.537
Mar. 11	51	30.13	17.3133	15.05	2.2633	74.89	.5000	1497	Mean of 2 experiments.	4.976	4.327
11	51	30.12	22.26	20.2866	1.9733	99.01	.6735	1470	Mean of 3 experiments.	4.883	4.448
13	53	30.15	22.04	20.095	1.945	96.90	.6665	1454	Mean of 2 experiments.	4.823	4.396
13	53	30.135	17.28	15.10	2.180	72.666	.50009	1453	Mean of 3 experiments.	4.812	4.205
13	51.4	30.12	11.93	9.9933	1.9333	47.947	.3317	1445	Mean of 3 experiments.	4.797	4.019
13	52	30.00	17.18	15.02	2.16	72.09	.5006	1473	Mean of 2 experiments.	4.800	4.196
13	70	29.98	17.11	14.90	2.21	75.91	.4970	1528	Mean of 2 experiments.	5.095	4.444
14	72	29.78	17.11	14.93	2.18	76.33	.5013	1522	Mean of 4 experiments.	5.107	4.461
Apr. 27	74	29.96	21.935	20.01	1.925	100.99	.6679	1513	Mean of 4 experiments.	5.048	4.604
27	74	29.95	17.145	14.97	2.175	75.83	.4990	1502	Mean of 4 experiments.	5.065	4.422
29	69	29.66	17.046	14.966	2.08	73.60	.5045	1458	Mean of 3 experiments.	4.920	4.317
29	71	29.68	11.7933	9.9733	1.82	47.94	.3360	1268	Mean of 3 experiments.	4.806	4.065
29	72	29.81	21.665	19.78	1.885	96.61	.6655	1482	Mean of 5 experiments.	4.980	4.551

Table of experiments—Continued.

February, 1850.	Thermometer.	Barometer.	Quantity of vapor generated.	Height of mercury after explosion.	Height of mercury after equilibrium of temperature.	Difference of two last, minus vapor generated.	Cold produced by expansion.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold of dry air for equal expansion.	Specific caloric of air.	Remarks.
COMMON AIR SATURATED WITH VAPOR INTO RAREFIED.												
Day.	°						°			°		
11	50	30.02	.....	16.02	14.52	.....	.....	.....	.....	.....	.....	
	50	30.05	.....	16.32	14.70	.....	.....	.....	.....	.....	.....	
	50	30.05	.....	16.20	14.64	.....	.....	.....	.....	.....	.....	
	50	30.05	.....	16.44	14.80	.....	.....	.....	.....	.....	.....	
	50	30.04	.....	16.24	14.62	.....	.....	.....	.....	.....	.....	
Mean	50	30.04	0.217	16.225	14.656	1.273	42.01	.4980	.2008	74.50	.17861	
11	51	30.04	.....	21.00	19.50	.....	.....	.....	.....	.....	.....	
	51	30.03	.....	21.08	19.52	.....	.....	.....	.....	.....	.....	
	51	30.01	.....	21.20	19.78	.....	.....	.....	.....	.....	.....	
	52	30.01	.....	21.18	19.62	.....	.....	.....	.....	.....	.....	
	52	30.00	.....	21.24	19.80	.....	.....	.....	.....	.....	.....	
Mean	51.4	30.02	0.345	21.140	19.645	1.150	58.73	.6673	.2660	102	.18000	
12	68	30.27	.....	16.30	14.98	.....	.....	.....	.....	.....	.....	
	68	30.27	.....	16.00	14.54	.....	.....	.....	.....	.....	.....	
	68	30.26	.....	16.16	14.64	.....	.....	.....	.....	.....	.....	
	68.2	30.26	.....	16.12	14.64	.....	.....	.....	.....	.....	.....	
Mean	68.05	30.265	0.470	16.145	14.675	1.00	34.08	.5003	.2600	75	.1627	
	68.00	30.26	.....	11.64	10.35	.....	.....	.....	.....	.....	.....	
	68.00	30.26	.....	11.08	9.84	.....	.....	.....	.....	.....	.....	
	68.00	30.26	.....	11.04	9.82	.....	.....	.....	.....	.....	.....	
Mean	.....	.....	.....	11.253	10.00	.....	22.20	.3346	.1918	50.00	.1695	
13	72.5	30.17	.....	16.20	14.68	.....	.....	.....	.....	.....	.....	
	72.5	30.17	.....	16.20	14.64	.....	.....	.....	.....	.....	.....	
Mean	72.5	30.17	0.500	16.20	14.66	1.08	37	.5044	.340	75.66	.2281	
13	72.5	30.17	.....	21.02	19.36	.....	.....	.....	.....	.....	.....	
	72.6	30.16	.....	21.22	19.50	.....	.....	.....	.....	.....	.....	
	72.5	30.16	.....	21.40	19.68	.....	.....	.....	.....	.....	.....	
	72.5	30.15	.....	21.30	19.63	.....	.....	.....	.....	.....	.....	
Mean	72.5	30.16	0.670	21.255	19.545	1.0425	54.6	.6610	.436	108.6	.2313	
14	68.70	29.36	.....	16.20	14.69	.....	.....	.....	.....	.....	.....	
	68.80	29.33	.....	16.28	14.74	.....	.....	.....	.....	.....	.....	
	68.90	29.33	.....	15.98	14.55	.....	.....	.....	.....	.....	.....	
	68.90	29.32	.....	15.98	14.54	.....	.....	.....	.....	.....	.....	
	68.91	29.32	.....	15.88	14.38	.....	.....	.....	.....	.....	.....	
Mean	68.86	29.33	0.500	16.064	14.58	0.984	36	.5098	.2900	77.80	.1899	
In the above experiments, if we suppose the temperature sunk one degree more than the calculation, it would then be below the freezing point, and the 140° of caloric of fluidity being in this case evolved, the specific caloric of the air would come out .2120.												
15	65	29.40	.....	21.58	20.08	.....	.....	.....	.....	.....	.....	
	65.1	29.41	.....	21.04	19.64	.....	.....	.....	.....	.....	.....	
	65.1	29.41	.....	20.88	19.26	.....	.....	.....	.....	.....	.....	
	65.1	29.43	.....	20.88	19.28	.....	.....	.....	.....	.....	.....	
	65.1	29.43	.....	20.80	19.18	.....	.....	.....	.....	.....	.....	
	65.0	29.43	.....	21.06	19.44	.....	.....	.....	.....	.....	.....	
	65.1	29.44	.....	20.88	19.34	.....	.....	.....	.....	.....	.....	
	65.1	29.44	.....	21.00	19.48	.....	.....	.....	.....	.....	.....	
Mean	65.1	29.42	0.5160	21.015	19.4625	1.0365	56.27	.6790	.3530	110.70	.1840	
15	65.1	29.46	.....	16.04	14.50	.....	.....	.....	.....	.....	.....	
	65.2	29.46	.....	15.94	14.44	.....	.....	.....	.....	.....	.....	
	65.2	29.47	.....	15.90	14.40	.....	.....	.....	.....	.....	.....	
Mean	65.2	29.46	0.4310	15.96	14.446	1.083	38.01	.5065	.2800	80.43	.1893	
15	67.00	29.63	.....	11.00	9.88	.....	.....	.....	.....	.....	.....	
	67.10	29.63	.....	10.80	9.66	.....	.....	.....	.....	.....	.....	
	67.00	29.64	.....	10.90	9.78	.....	.....	.....	.....	.....	.....	
	67.00	29.64	.....	10.86	9.70	.....	.....	.....	.....	.....	.....	
Mean	67.05	29.63	0.340	10.89	9.7550	7.950	21.09	.3341	.1800	50.44	.1582	
16	51.0	30.10	.....	23.62	22.36	.....	.....	.....	.....	.....	.....	

If it is supposed that the temperature sunk to just below 32° in this experiment, the specific caloric would come out .2200.

Table of experiments—Continued.

February, 1850.	Thermometer.	Barometer.	Quantity of vapor generated.	Height of mercury after explosion.	Height of mercury after equilibrium of temperature.	Difference of two last, minus vapor generated.	Cold produced by expansion.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold of dry air for equal expansion.	Specific caloric of air.	Remarks.
COMMON AIR SATURATED WITH VAPOR INTO RAREFIED.												
Day.	°						°			°		
16	51.5	30.11	.....	23.54	22.31	.....	.....	.....	.....	.....	.....	
	49.2	30.12	.....	23.52	22.23	.....	.....	.....	.....	.....	.....	
	49.2	30.13	.....	23.39	21.98	.....	.....	.....	.....	.....	.....	
Mean	50.0	30.11	0.3815	23.517	22.22	0.9155	60.50	.7528	.3200	117.58	.1665	
	.....	.....	.....	21.40	19.880	.....	.....	.....	.....	.....	.....	
	.....	.....	.....	21.21	19.74	.....	.....	.....	.....	.....	.....	
	.....	.....	.....	21.28	19.80	.....	.....	.....	.....	.....	.....	
Mean	.....	.....	0.420	21.293	19.806	1.067	55.27	.6693	.2700	107.50	.1849	
MOIST COMMON AIR INTO RAREFIED.												
16	49.4	30.14	.....	16.52	14.92	.....	.....	.....	.....	.....	.....	
	49.8	30.14	.....	16.54	14.87	.....	.....	.....	.....	.....	.....	
	51.0	30.14	.....	16.32	14.64	.....	.....	.....	.....	.....	.....	
	51.5	30.14	.....	16.40	14.78	.....	.....	.....	.....	.....	.....	
Mean	50.42	30.14	0.3658	16.445	14.8025	1.2767	44.20	.4991	.2234	76.55	.1983	
19	63.5	29.81	.....	11.22	9.94	.....	.....	.....	.....	.....	.....	
	63.4	29.82	.....	11.08	9.98	.....	.....	.....	.....	.....	.....	
	63	29.82	.....	11.09	9.84	.....	.....	.....	.....	.....	.....	
	62.5	29.83	.....	11.16	9.91	.....	.....	.....	.....	.....	.....	
Mean	63	29.83	0.320	11.14	9.92	0.900	23.46	.3409	.1900	51.44	.1743	
19	62.5	29.85	.....	21.06	19.68	.....	.....	.....	.....	.....	.....	
	62.5	29.85	.....	20.98	19.48	.....	.....	.....	.....	.....	.....	
	62.5	29.85	.....	20.94	19.50	.....	.....	.....	.....	.....	.....	
Mean	62.5	29.85	0.478	20.993	19.553	0.962	49.95	.6643	.3000	102.18	.1663	
19	62.50	29.85	.....	16.30	14.78	.....	.....	.....	.....	.....	.....	
	61.90	29.85	.....	16.24	14.72	.....	.....	.....	.....	.....	.....	
Mean	62.00	29.85	0.470	16.27	14.75	1.05	36.60	.5018	.2500	76.17	.1833	

Table of experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Height of mercury before explosion.	Height of mercury after explosion.	Difference of two last, minus vapor generated.	Cold produced by expansion.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold of dry air for equal expansion.	Specific caloric of air.
COMMON AIR PARTIALLY MOIST INTO RAREFIED.												
1850.	°	°						°			°	
March 11.....	.....	.....	30.24	.....	21.39	19.46	.....	.....	.....	.....	.....	.....
	47.4	32.0	30.22	.....	21.72	20.00	.....	.....	.....	.....	.....	.....
	48.0	33.0	30.20	.....	22.04	20.12	.....	.....	.....	.....	.....	.....
	48.5	35.0	30.20	.....	21.98	20.24	.....	.....	.....	.....	.....	.....
	49.0	35.0	30.18	.....	21.92	20.20	.....	.....	.....	.....	.....	.....
Mean	48.5	35.8	30.21	0.070	21.81	20.00	1.74	83.95	.6669	.1700	97.00	.2890
March 11.....	50	35	30.18	.....	17.20	15.38	.....	.....	.....	.....	.....	.....
	50	36	30.15	.....	16.88	15.04	.....	.....	.....	.....	.....	.....
	50	36	30.15	.....	16.90	15.08	.....	.....	.....	.....	.....	.....
Mean .....	.....	35.6	30.16	0.0707	16.9933	15.166	1.7566	58.17	.5030	.1490	74.00	.2747
March 13.....	50	41.5	30.10	.....	11.38	9.98	.....	.....	.....	.....	.....	.....
	49	41.5	30.06	.....	11.39	9.86	.....	.....	.....	.....	.....	.....
Mean	50	41.5	30.05	0.070	11.62	10.02	1.530	37.87	.3282	.1210	50.50	.2787
March 13.....	53.0	41.5	30.05	.....	16.56	14.70	.....	.....	.....	.....	.....	.....
	52.0	41.5	30.05	.....	16.60	14.84	.....	.....	.....	.....	.....	.....

Table of experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Height of mercury before explosion.	Height of mercury after explosion.	Difference of two last, minus vapor generated.	Cold produced by expansion.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold of dry air for equal expansion.	Specific caloric of air.
COMMON AIR PARTIALLY MOIST INTO RAREFIED.												
1850.	°	°						°			°	
March 13.....	52.0	41.5	30.04	.....	16.90	15.10	.....	.....	.....	.....	.....	.....
	52.0	41.7	30.04	.....	16.70	14.84	.....	.....	.....	.....	.....	.....
Mean				0.080	16.6866	14.88	1.7266	56.64	.4980	.1750	74.00	.2931
March 13.....	51.50	41.50	3.03	.....	21.40	19.68	.....	.....	.....	.....	.....	.....
	52.00	42.00	3.02	.....	21.48	19.80	.....	.....	.....	.....	.....	.....
	52.00	42.50	3.02	.....	21.60	19.96	.....	.....	.....	.....	.....	.....
	52.00	43.00	3.00	.....	21.50	19.82	.....	.....	.....	.....	.....	.....
Mean				0.0700	21.495	19.815	1.56	75.69	.6622	.2300	99.37	.2900
DRY AIR CONDENSED INTO ATMOSPHERE.												
March 1.....	72.5	.....	29.36	.....	48.70	6.90	.....	.....	.....	.....	.....	.....
	72.5	.....	29.36	.....	48.72	6.76	.....	.....	.....	.....	.....	.....
Mean .....				.....	48.71	6.83	.....	97.23	.5351	.....	.....	.....
March 1.....	72	.....	29.37	.....	42.30	6.40	.....	.....	.....	.....	.....	.....
	68.1	.....	29.54	.....	42.36	6.68	.....	.....	.....	.....	.....	.....
	68	.....	29.55	.....	42.76	6.40	.....	.....	.....	.....	.....	.....
	68.3	.....	29.56	.....	43.10	6.40	.....	.....	.....	.....	.....	.....
Mean.....	69.1	.....	.....	.....	42.63	6.465	.....	92.64	0.5014	.....	.....	.....
February 27.....	65	.....	30.05	.....	42.60	6.25	.....	.....	.....	.....	.....	.....
	65	.....	30.05	.....	42.00	5.95	.....	.....	.....	.....	.....	.....
	65	.....	30.05	.....	42.80	6.85	.....	.....	.....	.....	.....	.....
	65	.....	30.03	.....	43.60	6.66	.....	.....	.....	.....	.....	.....
	65.1	.....	30.01	.....	42.80	6.72	.....	.....	.....	.....	.....	.....
Mean.....	65	.....	.....	.....	42.76	6.486	.....	90.82	.4955	.....	.....	.....
February 27.....	70.00	.....	30.02	.....	31.00	4.85	.....	.....	.....	.....	.....	.....
	69.5	.....	30.03	.....	30.55	5.14	.....	.....	.....	.....	.....	.....
	69.4	.....	30.03	.....	31.00	4.90	.....	.....	.....	.....	.....	.....
Mean.....	69.6	.....	30.03	.....	30.85	4.9633	.....	73.45	.4251	.....	.....	.....
February 28.....	72	.....	30.00	.....	30.30	5.00	.....	.....	.....	.....	.....	.....
	71.2	.....	30.00	.....	30.00	4.76	.....	.....	.....	.....	.....	.....
	70	.....	29.96	.....	29.91	4.92	.....	.....	.....	.....	.....	.....
Mean.....	71.3	.....	29.99	.....	30.07	4.8933	.....	72.67	.4191	.....	.....	.....
February 28.....	69.00	.....	29.95	.....	48.00	6.70	.....	.....	.....	.....	.....	.....
	69.00	.....	29.94	.....	47.80	6.74	.....	.....	.....	.....	.....	.....
	69.00	.....	29.94	.....	48.60	6.94	.....	.....	.....	.....	.....	.....
Mean.....		.....	.....	.....	48.133	6.7933	.....	79.50	.5294	.....	95.52	.....
March 2.....	71.2	.....	29.90	.....	67.30	8.94	.....	.....	.....	.....	.....	.....
	71.5	.....	29.89	.....	67.40	8.62	.....	.....	.....	.....	.....	.....
	71.8	.....	29.88	.....	68.20	9.01	.....	.....	.....	.....	.....	.....
	71.5	.....	29.88	.....	68.00	9.00	.....	.....	.....	.....	.....	.....
Mean.....	71.5	.....	29.89	.....	67.725	8.8925	.....	96	.6023	.....	119.10	.....
March 4.....	41.00	.....	30.38	.....	41.81	6.36	.....	.....	.....	.....	.....	.....
	41.8	.....	30.38	.....	42.14	6.70	.....	.....	.....	.....	.....	.....
	41.5	.....	30.37	.....	42.46	6.74	.....	.....	.....	.....	.....	.....
Mean.....	41.4	.....	30.38	.....	42.30	6.71	.....	71.32	.4896	.....	88.55	.....
March 4.....	41.5	.....	30.36	.....	40.60	6.32	.....	68.60	.4689	.....	84.42	.....
	42.5	.....	30.30	.....	66.25	8.78	.....	87	.5952	.....	110.05	.....
	42.50	.....	30.30	.....	52.75	7.34	.....	79.86	.5467	.....	97.34	.....
	42.20	.....	30.30	.....	48.00	7.20	.....	.....	.....	.....	.....	.....
	43.50	.....	30.30	.....	48.36	7.00	.....	.....	.....	.....	.....	.....
	41.00	.....	30.30	.....	47.90	7.08	.....	.....	.....	.....	.....	.....
Mean of last three.	42.2	.....	30.30	.....	48.09	7.093	.....	73.90	.5220	.....	93.00	.....
March 5.....	44.00	.....	30.40	.....	69.00	8.68	.....	.....	.....	.....	.....	.....
	44.00	.....	30.38	.....	69.15	8.86	.....	.....	.....	.....	.....	.....
	44.40	.....	30.38	.....	69.50	8.98	.....	.....	.....	.....	.....	.....
	45.00	.....	30.37	.....	69.00	8.88	.....	.....	.....	.....	.....	.....
Mean.....	44.35	.....	30.38	.....	69.1625	8.85	.....	87.60	.6059	.....	110.99	.....

Table of experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Large vessel before explosion.	Large vessel after explosion.	Small vessel before explosion.	Small vessel after explosion.	Change, minus vapor generated.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold produced by expansion.	Cold of common dry air for equal expansion.
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DRY AIR CONDENSED INTO ATMOSPHERE.

1850.	°											°	
May 6	70		29.73				48.18	7.18	7.18				
	70		29.73				47.80	6.88	6.88				
	71	.....	29.73	.....	.....	.....	48.40	6.84	6.84	.....	.....	.....	.....
	71	.....	29.73	.....	.....	.....	48.24	6.72	6.72	.....	.....	.....	.....
Mean.....	70.5	.....	29.73	.....	.....	.....	48.155	6.905	6.905	.5276	.....	97.93	.....

DRY AIR CONDENSED INTO CONDENSED.

May 6	71.5	.....	29.74	.....	10.06+	11.20 +	48.72 +	17.70 +	.....	.....	.....	.....	.....
	72	.....	29.76	.....	10.10+	11.20 +	48.20 +	17.50 +	.....	.....	.....	.....	.....
	72	.....	29.79	.....	10.08+	11.26 +	48.06 +	17.50 +	.....	.....	.....	.....	.....
Mean.....	72	.....	29.76	.....	10.08+	11.22 +	48.323	17.566+	6.346+	.3936	.....	69.64	.....
6	72	.....	29.83	.....	19.94+	20.80 +	48.75 +	26.10 +	.....	.....	.....	.....	.....
	72	.....	29.83	.....	20.10+	21.05 +	47.60 +	25.92 +	.....	.....	.....	.....	.....
Mean.....	72	.....	29.83	.....	20.02+	20.925+	48.175+	26.01 +	5.085+	.2906	.....	47.35	.....
7	70	.....	30.16	.....	3.12+	4.06 +	30.30 +	8.32 +	.....	.....	.....	.....	.....
	70	.....	30.16	.....	2.70+	3.90 +	30.28 +	8.18 +	.....	.....	.....	.....	.....
Mean.....	70	.....	30.16	.....	2.91	3.98 +	30.29	8.24 +	4.29 +	.3662	.....	57.21	.....

DRY AIR CONDENSED INTO RAREFIED.

May 7	70	.....	30.15	.....	6.40—	5.26 —	29.90 +	0.48 —	.....	.....	.....	.....	.....
	70	.....	30.15	.....	5.80—	4.58 —	30.50 +	0.02 +	.....	.....	.....	.....	.....
Mean.....	70	.....	30.15	.....	6.10—	4.92 —	30.20	0.23 —	4.69 —	.5015	.....	81.20	.....

Table of experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Height of mercury before explosion.	Height of mercury after explosion.	Height of mercury after equilibrium of temperature.	Change, minus vapor generated.	Expansion, or quotient of air discharged by whole quantity of air.	Cold produced by expansion.	Cold of dry air for equal expansion.	Quantity of vapor condensed.	Specific caloric of air.
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DRY COMMON AIR INTO RAREFIED.

1850.	°									°	°		
April 27	74.2		29.98			21.90	19.90						
	74.0		29.96			22.04	20.10						
	73.5	.....	29.96	.....	.....	21.90	20.00	.....	.....	.....	.....	.....	.....
	73	.....	29.96	.....	.....	21.90	20.04	.....	.....	.....	.....	.....	.....
Mean.....	73.5	.....	29.96	.....	.....	21.935	20.01	1.925	.6678	100.99	.....	.....	.....
27	47.0	.....	29.96	.....	.....	17.20	15.08	.....	.....	.....	.....	.....	.....
	74.0	.....	29.95	.....	.....	17.10	14.86	.....	.....	.....	.....	.....	.....
	74.0	.....	29.95	.....	.....	17.22	15.10	.....	.....	.....	.....	.....	.....
	74.0	.....	29.95	.....	.....	17.16	14.84	.....	.....	.....	.....	.....	.....
Mean	45.00	.....	29.95	.....	.....	17.145	14.97	2.175	.4990	75.83	.....	.....	.....

Table of experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Height of mercury before explosion.	Height of mercury after explosion.	Height of mercury after equilibrium of temperature.	Change, minus vapor generated.	Expansion, or quotient of air discharged by whole quantity of air.	Cold produced by expansion.	Cold of dry air for equal expansion.	Quantity of vapor condensed.	Specific caloric of air.
PARTIALLY MOIST AIR—COMMON INTO RAREFIED.													
1850.	°									°	°		
April 27	76	59.0	30.00	.....	.....	16.72	15.18	.....	.....	.....	.....	.....	.....
	75.2	59.5	30.00	.....	.....	16.52	15.00	.....	.....	.....	.....	.....	.....
	75	60.0	30.00	.....	.....	16.46	14.86	.....	.....	.....	.....	.....	.....
Mean	75.3	59.5	30.00	.....	.....	16.566	15.05	1.416	.5033	50.96	76.00	.2100	.2360
27	75	60.0	30.00	.....	.....	21.40	20.00	.....	.....	.....	.....	.....	.....
	74.6	59.0	29.98	.....	.....	21.48	20.00	.....	.....	.....	.....	.....	.....
Mean	74.8	59.5	29.99	.....	.....	21.44	20.00	1.354	.6702	71.80	102.00	.284	.2737

Table of Experiments—Continued.

Month and day.	Thermometer.	Barometer.	Large vessel before explosion.	Large vessel after explosion.	Small vessel before explosion.	Small vessel after explosion.	Change, minus whole vapor generated.	Expansion, or quotient of air discharged by whole quantity of air.	Cold produced by expansion.	Cold produced for one inch of mercury.
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DRY AIR CONDENSED INTO RAREFIED.

1850.	°						°		°	
May 8	66.0	30.10		4.04—	29.40 +	0.16+				
	67.5	30.09	5.60—	4.36—	30.40 +	0.44+				
	68.0	30.09	5.92—	4.82—	30.08 +	0.10—	.....	.....	.....	.....
	68.6	30.08	5.84—	4.58—	30.04 +	0.04—	.....	.....	.....	.....
	69.0	30.05	5.80—	4.60—	29.70 +	0.06—	.....	.....	.....	.....
Mean.....	67.7	30.08	5.7855	4.46—	29.925+	0.08+	4.540	.4980	77.62	2.569

DRY AIR CONDENSED INTO CONDENSED.

May 8	70	30.00	6.16+	7.08 +	30.08 +	11.18 +	.....	.....	.....	.....
	70	29.97	5.60+	6.46 +	30.06 +	10.50 +	.....	.....	.....	.....
	70	29.95	5.30+	6.18 +	30.00 +	10.20 +	.....	.....	.....	.....
Mean.....	70	29.97	.....	6.573+	30.046+	10.626+	4.053+	.3235	51.74	2.669
10	69.0	29.96	4.90+	5.82 +	30.00 +	9.98 +	.....	.....	.....	.....
	68.6	29.96	4.94+	5.76 +	29.88 +	9.90 +	.....	.....	.....	.....
Mean.....	68.8	29.96	4.92	5.79 +	29.94 +	9.94 +	4.15 +	.3338	53.77	2.68

DRY AIR CONDENSED INTO RAREFIED.

May 10	70	30.00	11.96—	10.90—	30.06+	6.16—	4.74	.6027	103.37	2.853
	70	30.00	14.70—	13.30—	29.48+	8.48—	4.82	.6550	111.36	2.938
	69	30.00	16.18—	14.80—	30.00+	10.00—	4.80	.66667	124.32	3.108
	70	30.02	16.20—	14.76—	30.24	9.92—	4.84	.66644	124.70	3.105

Table of Experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Large vessel before expansion.	Large vessel after expansion.	Small vessel before expansion.	Small vessel after expansion.	Change, minus vapor generated.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold produced by expansion.	Cold of dry air for equal expansion.	Specific caloric of air.
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DRY AIR CONDENSED INTO RAREFIED.

1850.														
May 18	65°		29.85		6.00—	4.68—	29.80 +	0.44 +						
	65		29.85		6.04—	5.00—	30.10 +	0.16 +						
	65.5	.....	29.85	.....	6.12—	4.90—	29.88 +	0.18 +	.....	.....	.....	.....	.....	.....
	66	.....	29.86	.....	6.34—	5.10—	29.88 +	0.04 +	.....	.....	.....	.....	.....	.....
Mean.....	65.5	.....	29.85	.....	6.125	4.92—	29.915+	0.205+	5.125	.4964	.....	.....	88.15°	.....

DRY AIR CONDENSED INTO CONDENSED.

May 18	69	.....	29.86	.....	5.32+	6.24+	29.88+	10.50+	.....	.....	.....	.....	.....	.....
	70	.....	29.86	.....	4.90+	5.88+	30.20+	10.10+	.....	.....	.....	.....	.....	.....
	71	.....	29.86	.....	4.70+	5.61+	30.08+	10.00+	.....	.....	.....	.....	.....	.....
Mean.....	70	.....	29.86	.....	4.97	5.91+	30.05+	10.20+	4.29+	.3313	.....	.....	55.34	.....

PARTIALLY MOIST AIR CONDENSED INTO CONDENSED.

May 18	71	40°	29.86	.....	5.84+	6.80+	31.24+	10.20+	.....	.....	.....	.....	.....	.....
	71.5	40	29.87	.....	4.90+	6.82+	31.26+	10.10+	.....	.....	.....	.....	.....	.....
	71.5	40	29.88	.....	5.95+	6.80+	29.60+	9.80+	.....	.....	.....	.....	.....	.....
	71.5	42	29.88	.....	6.04+	6.90+	30.10+	10.00+	.....	.....	.....	.....	.....	.....
Mean.....	71.5	40.5	29.87	0.113	5.932	6.83+	30.55+	10.07+	3.127	.3341	.2444	40.00°	57.50	.1709

PARTIALLY MOIST AIR CONDENSED INTO RAREFIED.

May 18	71	44	29.87	.....	5.10—	3.92 —	29.60 +	0.28—	.....	.....	.....	.....	.....	.....
	71	43.5	29.87	.....	4.90—	3.66 —	30.10 +	0.18+	.....	.....	.....	.....	.....	.....
	70.08	44	29.87	.....	4.90—	3.68 —	29.80 +	0.02+	.....	.....	.....	.....	.....	.....
Mean.....	71	43.83	29.87	.....	4.97—	3.753—	29.833+	0.03—	3.5123—	.4967	.4230	60.51	88.55	.2188

See experiment on May 7, where the cold of dry air was 81°.21; and if the mean of these two (81°.88) be used, the specific caloric will come out 25.18.

Table of Experiments—Continued.

Date.	Thermometer.	Dew-point.	Barometer.	Quantity of vapor generated.	Height of mercury before explosion.	Height of mercury after explosion.	Difference of last two, minus vapor generated.	Cold produced by expansion.	Expansion, or quotient of air discharged by whole quantity of air.	Quantity of vapor condensed.	Cold of dry air of equal expansion.	Specific caloric of air.
MOIST CONDENSED AIR INTO ATMOSPHERE.												
1850.	°							°			°	
February 27	65.20	.....	30.00	.....	41.90	.....	.....	.....	.....	.....	.....	.....
	65.30	.....	30.00	.....	42.00	.....	.....	.....	.....	.....	.....	.....
	65.90	.....	30.00	.....	41.95	.....	.....	.....	.....	.....	.....	.....
	68.90	.....	30.01	.....	42.24	.....	.....	.....	.....	.....	.....	.....
Mean.....	66.22	.....	30.00	.....	42.0225	4.9625	.....	64.00	.5362	.4900	98.00	.1745
27	70.00	.....	30.00	.....	28.85	3.28	.....	.....	.....	.....	.....	.....
	71.00	.....	30.00	.....	29.40	3.36	.....	.....	.....	.....	.....	.....
	71.00	.....	30.02	.....	29.00	3.30	.....	.....	.....	.....	.....	.....
Mean.....	71.00	.....	30.01	.....	29.1833	3.3133	.....	42.64	.4476	.5300	80.00	.1800
28	68.60	.....	29.90	.....	46.60	5.20	.....	.....	.....	.....	.....	.....
	68.50	.....	29.89	.....	45.90	5.10	.....	.....	.....	.....	.....	.....
	68.00	.....	29.87	.....	47.10	5.42	.....	.....	.....	.....	.....	.....
Mean.....	68.40	.....	29.89	.....	46.20	5.24	.....	69.37	.5456	.5550	97.93	.1833
28	68.20	.....	29.86	.....	41.90	4.50	.....	.....	.....	.....	.....	.....
	67.00	.....	29.85	.....	42.30	4.90	.....	.....	.....	.....	.....	.....
Mean.....	67.06	.....	29.855	.....	42.10	4.70	.....	61.78	.5267	.5200	95.40	.1850
March 1	67.50	.....	29.25	.....	33.92	4.00	.....	.....	.....	.....	.....	.....
	69.20	.....	29.27	.....	33.94	4.00	.....	.....	.....	.....	.....	.....
	68.80	.....	29.27	.....	32.72	3.76	.....	.....	.....	.....	.....	.....
	69.00	.....	29.27	.....	32.56	3.76	.....	.....	.....	.....	.....	.....
	69.00	.....	29.30	.....	33.14	3.30	.....	.....	.....	.....	.....	.....
	69.20	.....	29.30	.....	33.46	3.90	.....	.....	.....	.....	.....	.....
Mean.....	68.54	.....	29.27	.....	33.29	3.7866	.....	51.00	.4808	.4808	88.54	.1734
1	70.10	.....	29.33	.....	41.02	4.90	.....	.....	.....	.....	.....	.....
	71.00	.....	29.34	.....	41.04	4.70	.....	.....	.....	.....	.....	.....
	71.20	.....	29.35	.....	41.06	4.46	.....	.....	.....	.....	.....	.....
Mean.....	71.10	.....	29.34	.....	41.04	4.6866	.....	67.95	.5203	.5800	102.00	.1947
4	41.80	.....	30.30	.....	44.88	5.64	.....	.....	.....	.....	.....	.....
	41.80	.....	30.30	.....	42.08	5.48	.....	.....	.....	.....	.....	.....
	42.60	.....	30.30	.....	41.02	5.54	.....	.....	.....	.....	.....	.....
Mean.....	42.00	.....	30.30	.....	41.55	5.51	.....	72.12	.5054	.2800	90.97	.1830
2	91.20	.....	29.90	.....	65.50	6.70	.....	.....	.....	.....	.....	.....
	71.50	.....	29.89	.....	65.70	6.90	.....	.....	.....	.....	.....	.....
	71.80	.....	29.88	.....	66.00	6.90	.....	.....	.....	.....	.....	.....
	71.50	.....	29.88	.....	66.06	6.80	.....	.....	.....	.....	.....	.....
Mean.....	71.50	.....	29.89	.....	65.815	6.85	.....	88.73	.6237	.6870	123.00	.1488
4	39.90	.....	30.37	.....	41.60	5.70	.....	.....	.....	.....	.....	.....
	40.20	.....	30.37	.....	41.30	5.76	.....	.....	.....	.....	.....	.....
	39.00	.....	30.38	.....	42.30	5.54	.....	.....	.....	.....	.....	.....
	39.50	.....	30.38	.....	42.00	5.50	.....	.....	.....	.....	.....	.....
Mean.....	39.90	.....	30.375	.....	41.80	5.625	.....	73.07	.5046	.2600	90.828	.1852
7	52.00	.....	29.53	.....	68.80	7.34	.....	99.64	.6349	.....	119.93	.1705
	51.80	.....	29.55	.....	69.10	7.54	.....	97.57	.6274	.....	118.30	.1708
	51.70	.....	29.55	.....	67.55	7.40	.....	95.78	.6230	.....	118.20	.1614
	51.70	.....	29.55	.....	68.20	7.46	.....	96.44	.6250	.....	118.25	.1606
	51.40	.....	20.55	.....	66.50	7.30	.....	94.32	.6162	.....	115.50	.1666
	51.00	.....	29.57	.....	63.95	7.24	.....	91.18	.6105	.....	114.88	.1621
	51.00	.....	29.58	.....	62.62	6.92	.....	90.30	.6084	.....	114.40	.1546
	51.30	.....	29.60	.....	58.34	6.90	.....	90.07	.5089	.....	111.20	.1758
	51.50	.....	29.60	.....	56.30	6.60	.....	86.59	.5852	.....	110.30	.1704
	51.60	.....	29.60	.....	60.05	6.90	.....	92.79	.5883	.....	111.00	.2142
Mean.....	51.50	.....	29.57	.....	64.74	7.16	.....	93.47	.6109	.....	115.52	.1707

WASHINGTON, October 21, 1850.

141. From an examination of the foregoing tables, I have been enabled to deduce, for the expansion of dry air at mean pressure, the following

LAWS OF COOLING IN DRY AIR.

When the air is at the temperature of 52° Fahrenheit, a discharge of ten inches gives a cold of about 47° —that is, $4^{\circ}.70$ for each inch; a discharge of fifteen inches—that is, one half the quantity—gives about 72° —that is, $4^{\circ}.80$ for each inch; and a discharge of twenty inches gives about 100° of cold—that is, 5° for each inch; and, according to this rate, a discharge of 30 inches would give about 162° —that is, $5^{\circ}.40$ for each inch of discharge; so that, if air at the temperature of 52° should be relieved from all pressure in expanding into vacuum, it would cool 162° , and be then 110° below zero.

142. From this it follows, in connexion with previous reasonings, that, in the normal state of the atmosphere, when the temperature of the air at the surface of the earth is 52° , the temperature of the top of the atmosphere at the same place is 110° below zero. When the temperature varies from 52° , the cold produced for equal expansions is one per centum greater for every five degrees above 52° , and one per centum less for every five degrees below 52° ; so that, when the air below is at 82° , it is colder at the top by $171^{\circ}.42$, and is therefore $89^{\circ}.42$ below zero, which is about the temperature of the equatorial regions. So, when the air below is at the temperature of two degrees, as it is in the frigid zones, it is colder at the top by $145^{\circ}.80$, and is therefore $143^{\circ}.80$ below zero.

During the time of greatest cold in the frigid zone, if the temperature below is assumed to be about 60° below zero, it is colder at the top by $128^{\circ}.40$, and is therefore $188^{\circ}.40$ below zero. This result is only 35° above the temperature of the interplanetary spaces, according to the very ingenious experiments of M. Pouillet with his actinometer,* and entirely disproves the

* These experiments of mine, founded on entirely different principles, give a high degree of probability to M. Pouillet's results, as will more fully appear from the following consideration:

The interplanetary spaces are colder than the top of the atmosphere wherever there is either snow or rain, because, wherever these occur, there are up-moving currents, and there would not be up-moving currents if the caloric evolved by the condensing vapor were not radiated away; and it would not be radiated away unless the interplanetary spaces were colder than itself. Now, there are snows in the winter season not far from the region of the greatest cold, and, therefore, the interplanetary spaces are colder than the upper air very near the regions of greatest cold, and, of course, cannot be warmer than the upper regions of the air at the point of greatest cold.

Again: The interplanetary space cannot be *very much* colder than the top of the atmosphere in the region of greatest cold; because, if it was, the upper air there, during the time that it is receiving no caloric from condensing vapor, and none from the rays of the sun for several months, would become so cold by radiation that it would, by its greater specific gravity, produce a down-moving current of considerable violence, and a proportionably strong outward motion below from the pole; but this is not the case; it is generally nearly calm in those high latitudes, at least in the middle of North America, during the time of greatest cold. From the clearness of the sky, and from the known prevalence of winds from the poles during the same time, it is probable there is a gentle downward motion of the air in this cold region corresponding with the fact, and leading to the conclusion, that the space surrounding the atmosphere is not very many degrees colder than the top of the atmosphere in the region of greatest cold.

There is another consideration from which this same conclusion may be drawn with the utmost confidence in its correctness. It is known that the radiation of caloric from the surface of the earth in clear evenings is so rapid as to cause a depression of temperature of ten, fifteen, and even twenty degrees in a few hours; and, by an examination of M. Pouillet's experiments with his actinometer, it will be seen that there is a greater fall in the temperature of the upper air at the same time than of the lower. Now, the stability of temperature for weeks, and even months, in the regions of greatest cold, while it is receiving no heat, or but little, from the sun, and none from latent caloric from condensing vapor, *because no clouds are then formed in these regions*, proves that the upper air cannot be very many degrees above the temperature of surrounding space. As the air, however, in this coldest region is colder and dryer, and, of course, heavier than that in surrounding

result obtained by Fourier, which makes the temperature of space about the same as the lowest temperature at the surface of the earth in the frigid zones. It certainly is lower than the temperature of the surface of the atmosphere in those regions—that is, more than 118° colder than Fourier makes it.

From the tables of condensed dry air it appears that, for a given expansion, *a greater cold is produced in air of greater density.*

A double density gives an increase of cold of $15\frac{1}{2}$ per cent. ; $2\frac{3}{5}$ density gives an increase of cold of $20\frac{1}{5}$ per cent. ; and $3\frac{1}{5}$ density gives an increase of cold of 26 per cent.

143. By examining the tables of partially moist air I have been enabled to deduce the following

LAWS OF COOLING IN PARTIALLY MOIST AIR.

In up-moving currents of air producing clouds and rain, the temperature of the atmosphere, from the top of the cloud upwards to the top of the atmosphere, will be about one degree warmer than its normal state for each hundredth of an inch of elastic force of vapor condensed by the cold of diminished pressure as it ascends.

For example: When the dew-point is 32° —that is, when the elastic force of the vapor is 0.200 inch, the air will have been prevented from cooling 20° by the time it has ascended high enough to condense all its vapor ; and when the elastic force of vapor in the air is 0.400 inch, at which time the dew-point is 52° , the air will have been prevented from cooling 40° , when it has ascended high enough to condense all its vapor.

If the dew-point is above 64° —that is, if the elastic force of vapor is over 0.600 inch, then the superabundance over 0.600 inch is not condensed, even at the greatest heights, but goes on *transparent* to the top of the atmosphere from the point where it ceases to condense.

It follows, therefore, that when the elastic force of vapor is 0.800 inch, as it is in the torrid zone over the sea, only three-fourths of the vapor is condensed in going up to where the barometer stands 25 inches below 30 ; and, beyond that height, no more is condensed, as was shown before, [No. 64,] the remaining vapor going up transparent with the ascending air, now 60° hotter than the air on the outside of the ascending current, at the same elevation, all the way to the top of the atmosphere.

regions, it has a gentle down-moving current, consequently an in-moving current, above ; and this in-moving current must carry with it its own temperature, except so far as it becomes colder by radiation ; and as it was shown before that, on sinking even one degree below its normal state, it would produce a down-moving current, it is manifest that it never sinks many degrees, otherwise its downward velocity would be considerable, and its outward motion below would be great and constant during the whole period of very great cold. Now, this is not the case ; but, on the contrary, the wind at that period is variable, though chiefly from the pole, in latitude 75° to 80° ; therefore, the air in the upper regions is but little below the normal state in temperature near the pole ; and, therefore, it cannot be very *many*, though it is certainly *some*, degrees above the temperature of surrounding space.

By the temperature of surrounding space, I mean the temperature that a thermometer would have if placed above the atmosphere and not exposed to the sun's rays.

It is true that, during the long winter night in the polar regions, the uppermost strata of air would take the temperature of surrounding space nearly, if it were not that the air above from surrounding regions (where it was shown before there are almost constant rains) unceasingly flowed towards the place of greatest cold, where the perpendicular column of the atmosphere is the shortest. I agree with M. Pouillet (Scientific Memoirs, November, 1844) that, from the nature of the absorbent powers of the atmosphere for the heat radiated from the stars, the surface of the earth would be considerably higher than the temperature of space if the earth's surface should receive no heat either from the sun or from the interior heat of the globe ; but I cannot agree with him that the upper stratum of the atmosphere would then be colder than space, much less can I agree with him that the mean temperature of the atmosphere would be colder ; for a stratum of matter cannot intervene between two strata of different temperatures and remain forever colder than the coldest.

144. The temperature of space above the atmosphere is certainly some degrees, though not very many, below the temperature of the top of the atmosphere in the coldest region at the time of the greatest cold, as is shown in the last note, and is therefore certainly some degrees, probably 30° or 40° , more than 188° below zero. M. Pouillet has shown that the temperature of space is not colder than 283° below zero of Fahrenheit, and not warmer than 175° below zero.

As there is a much greater difference of temperature in very warm latitudes than in very cold, between the upper air and surrounding space, the superabundance of heat in the upper air after rain storms will be much more rapidly radiated off into space in hot than in cold regions, and thus sooner prepared to permit other columns of air to ascend to produce other rains.

For it is manifest, if space were as warm as the upper air after a rain, no rains could ever take place, for there would then be no ascending columns of air from below, on account of the air below containing less caloric for equal weights than the air above. It will hardly be contended (see last note) that the upper air will radiate off any of its caloric if it is no warmer than the space which surrounds it; and it is manifest that, when the air above contains more caloric than the air below—weight for weight—its equilibrium is stable; so that the air above will not sink down into the air below, nor will the air below rise up into the air above.

Finally, I may add, that the laws deduced from the experiments detailed in this report, with the explanation of various phenomena, heretofore not explained, leave the theory of storms, given in the early part of this report, scarcely less certain than the theory of gravitation itself.

I have the honor to be, very respectfully, yours,

JAMES P. ESPY.

Hon. JAMES C. DOBBIN,
Secretary of the Navy.

P. S.—As the pamphlet containing "Rules for the Mariner" is out of print, I append these rules to this report, with such parts of the last report as are necessary to render them fully intelligible.

J. P. E.

COMMUNICATION FROM THE SECRETARY OF THE NAVY, WITH PROFESSOR ESPY'S "RULES FOR THE MARINER," FOUNDED ON HIS THEORY OF STORMS.

NAVY DEPARTMENT, *January 30, 1851.*

SIR: Agreeably to the request of Professor Espy, as expressed in his letter of this date, a copy of which is enclosed, I have the honor to transmit herewith the accompanying "Rules for the Mariner," in connexion with his theory of storms, with a view to their being printed with his report, now in press, by order of the Senate.

I have the honor to be, very respectfully, your obedient servant,

WILL. A. GRAHAM.

Hon. D. L. YULEE,

Chairman of the Committee on Naval Affairs.

WASHINGTON, *January 30, 1851.*

SIR: Agreeably to your directions, contained in your letter to me of the 10th instant, I have written out rules to aid the mariner to understand the nature of storms and to predict their approach, and in many cases to avoid their destructive violence.

As these rules are founded on the theory and facts contained in my second and third reports to the department, I respectfully suggest that they be sent to the Senate in time to be printed at the end of the report now in the press by order of that body. The rules will be much better understood in connexion with the report than they would be if printed alone. The rules are herewith enclosed.

With high respect, I remain your very humble servant,

JAMES P. ESPY.

Hon. WILLIAM A. GRAHAM,

Secretary of the Navy.

DIRECTIONS TO MARINERS.

145. Atmospheric air is expanded about one four hundred and eightieth of its bulk at 32° Fahrenheit for each degree that it is heated.

If a column of the atmosphere—say of 20 or 40 or 100 miles wide—reaching from the surface of the earth to the surface of the atmosphere, should have a mean temperature of 33° , whilst surrounding columns are at 32° , and if these columns are all of the same height, then would the hottest column be one four hundred and eightieth lighter than the surrounding columns; and this difference of weight would be indicated by the barometer.

If the difference of temperature were greater, then the difference of weight would be greater in the same proportion.

Moreover, the air at the surface of the earth would move on all sides from the columns of greater weight towards the columns of less weight, with a velocity proportional to the square root of the fall of the barometer; a fall of one inch giving a velocity of 240 feet per second, provided no allowance be made for friction on the roughness of the earth's surface.

The column of greater heat and less weight will, therefore, be an up-moving column, and, in ascending, it will come under less pressure and expand; and, in expanding, will become colder, about as fast as the atmosphere becomes colder at greater heights—that is, a little more than one degree for each hundred yards—until it rises high enough to begin to condense its vapor, which it carries up with it into cloud: from that point upwards the latent caloric evolved into the air by the condensing vapor will cause the air to cool less than it did before for a given increase of elevation. For each hundredth of an inch of elastic force of vapor condensed, the air in the ascending column at the height when this quantity of vapor is condensed by the cold of expansion, by diminished pressure will be one degree less cold than if it had had no vapor in it to condense—*i. e.*, if the elastic force of vapor, as indicated by the dew-point, is 0.50 inch, then, when the air in the ascending column has risen high enough to condense all its vapor by the cold of expansion from diminished pressure, its temperature will be about 50° higher than it would be if it had had no vapor to condense, and no latent caloric to give out; and therefore it will now be about 50° degrees warmer than the air on the outside of the ascending column at the same height. It will therefore be about fifty five hundred and thirtieths lighter, and the barometer will fall at the base of the ascending column in proportion to the diminished pressure, and the force of the wind blowing inwards on all sides will be in the same proportion, or, which is the same thing, the velocity of the inward motion at the sides of the ascending column, and of the upward motion of the column in which the cloud is formed and the latent caloric is evolved, will be in proportion to the square root of the fall of the barometer below.

The temperature of the air in the up-moving column will fall about one degree and a quarter for a hundred yards whilst it is near the surface of the earth; and, as the dew-point falls by expansion about one-quarter of a degree, the clouds will begin to form at about as many hundred yards high as the temperature of the air at the surface of the earth is above the dew-point in degrees of Fahrenheit.

The distance to which the air will have to rise before all the vapor is condensed by the cold of expansion from diminished pressure is greater in proportion as the quantity of vapor in the air is greater, until the quantity reaches a pressure of 0.60 inch, when the top of the cloud will be at a height where the barometer would indicate a pressure of between five and six inches of mercury; and above that point no more vapor will be condensed, however high the dew-point may be. In this latter case, the air at the top of the cloud, and from that to the top of the atmosphere, will be 60° warmer than the surrounding air at equal heights. During the condensation of the vapor in the up-moving column of air, the expansion caused by the evolution of the latent caloric will cause the air to spread outwards above in all directions from the centre of the up-moving column, thus causing the barometer to rise all round the borders of a storm cloud.

As in middle latitudes—the Atlantic, for example, between the United States and Europe—it is known, from the general direction of the upper clouds, that the upper current of air moves from the west, and as the greatest part of a storm cloud is formed in this upper current, it follows that the storm cloud must move in these latitudes towards the east, and with it the storm itself; for the barometer must fall under the storm cloud wherever it appears, and the wind must blow from all sides towards the region where the barometer indicates less pressure.

146. *Rules for the mariner, deduced from the investigation of storms in my Philosophy of Storms, and in my three reports on Meteorology.*

The great winter storms in the Atlantic ocean, from latitude 30° to latitude 50° , travel towards the east. While they are yet eight or ten hundred miles from the observer the barometer will rise pretty suddenly above the mean, with but little wind and a clear sky. As the storm approaches, the barometer will begin to sink, and the wind will begin to blow from the eastward, increasing in force, with a falling barometer. The upper or front edge of the storm cloud will be seen in the west, in the form of an arch, gradually rising towards the zenith, with the wind below blowing in under it from the eastward, generally nearly towards the highest part of the arch. This upper edge or rim of the storm cloud will frequently reach the zenith, and even pass it towards the east, before the lower clouds form in such numbers as to conceal the majestic march of the upper cloud from view. When the lower clouds begin to form, they will be seen moving from the eastward, the same as the wind on the surface of the sea. These lower clouds are going to join the great storm cloud in the central regions of the storm, where they ascend.

When these phenomena all occur *the storm is sure to come on*, and will frequently commence before the barometer sinks to the mean. The longer these phenomena last before the storm comes on the longer will the storm last, though, for a given depression of the barometer, the wind will not be so violent as when the changes in the barometer are more rapid.

147. If the middle of the storm passes over the observer there will be a dead calm, with a *minimum barometer*, at the time of its passage; and this calm will be longer in proportion to the width of the storm from east to west; but in all cases preparation should be made to receive the wind, which will now come out from the westward with a fury proportionate to the suddenness and greatness of the depression of the barometer.

148. The barometer will now begin to rise, and in general the wind will continue violent until the barometer has risen to nearly a mean; but as soon as the barometer has risen two or three tenths of an inch no return of the wind from the east may be feared in this storm: it will continue from the west till the end of the storm. If the wind changes by the south to the westward about the time the barometer is at its lowest point to the observer, *without a lull*, then has the centre of the storm passed by the observer to the north of him, and the wind may be expected from the south of west during the rest of the gale. If the wind changes by the north to the westward without a lull, then has the centre of the storm passed the observer to the south of him, and the wind may be expected from the north of west during the rest of the gale. If the wind sets in very far north of east, as it frequently does in latitudes from 40° to 50° , it may be expected to change round to the westward, without a lull, by the *north*; and if the wind sets in far south of east, as it frequently does from latitudes 30° to 40° , it may be expected to change to the westward by the *south* without a lull; but in all cases the barometer will begin to rise as soon as the wind has much westing.

Whenever the wind changes to the westward by the north the snow or rain will not continue long, though the wind may continue for some time, even days; but when the wind changes round by the south to west the rain will be of longer continuance, though hardly ever so long as it lasted while the wind was easterly, except in the very southern borders of the storm.

149. The above *rules for great winter storms* in the Atlantic between the United States and Europe will be found to be correct, if storms follow the same laws in the Atlantic as they do in crossing the United States from Missouri to Maine and Halifax. It is nearly certain that these rules apply to all winter storms near the coast of the United States. *In low latitudes*, between 10° and 25° north, the great hurricanes of the West Indies, and Bay of Bengal, and the China sea move towards the northwest, as is shown by Redfield, Reid, and Piddington. When the centre of these hurricanes passes over an observer, the wind, according to my theory, confirmed by the most careful examination of all the facts that have come within my reach, will commence violently from the north to the northwest and terminate from the south to the southeast.—(See below in this paragraph.) Previous to the commencement of this violent wind there will generally be an increase of temperature, and the barometer will rise pretty suddenly above the mean, and then fall very low during the passage of the storm; and at the moment of greatest depression there will be a lull for a very short time; and when the barometer begins to rise the wind will spring up from the southeast with great violence, from which direction it will blow till the end of the storm. As these hurricanes move towards the northwest in these low latitudes, and as they are quite small, from fifty to one hundred miles in diameter, *the great violence of the wind may be avoided by sailing out of the direction in which they move*. If the wind becomes violent from the northwest the mariner may sail either to the southwest or northeast, as will best suit his course; but if he sails *with* the wind he will go directly into the heart of the storm. If the wind should be west of northwest let him sail to the southwest; but if the wind should be near the north let him sail to the northeast or east; and whenever the wind gets round to the south or southeast, with a rising barometer, he may be sure the centre of the hurricane is passed, and that it will never return; but even then he must *be careful not to sail with the wind*, otherwise, as the hurricanes in these latitudes move slowly, he may run right into the heart of the storm. As soon, however, as the wind becomes moderate from the south or southeast, with a barometer risen near to the mean, no more violence need be feared, and the remaining wind of the storm may be used for the purpose of navigation, with as much canvas set as the stiffness of the breeze will allow. The above rules for hurricanes in low latitudes are formed on the supposition that these hurricanes are *round*; but if it shall be found by more extensive observations that they are *oblong*, which is not improbable, then some of the rules will require slight modification.

The following facts go far, independent of theory, to justify the rule here laid down, and besides, so far as the leading fact deducible from my theory is concerned, it demonstrates that fact to be true, namely: the inblowing of the air towards the centre of hurricanes in the West Indies and Bay of Bengal. Edwards, in his History of Jamaica, Vol. 3d, says: "All hurricanes begin from the N., veer back to the N.N.W., W., and S.S.W., and when got round to S.E. the foul weather breaks up."

He also says in the same volume: "When the wind is S. and S.W. on the south side of the island, it is often northeasterly on the north side, attended with heavy rains."

Colonel Capper, speaking of the great hurricane which occurred on the Coromandel coast on the 29th October, 1768, page 60, says: "The wind began from the N.W. *as is usual at the commencement of these hurricanes*." And Colonel Reid says: "This same hurricane *terminated*

S.E.," page 264; and on the next page he says of another hurricane, quoting from Colonel Capper: "*It began in the N.W. and suddenly shifted to the eastward.*"

So, in the great Barbadoes hurricane of 1831, August 10 and 11, as given by the author of the West Indian, and quoted by Colonel Reid, "the wind began N., varying from N.N.E. to N.N.W. during the first half of the storm, but strongest from the N.W. and N.N.W., and terminated from the S.E., though it once reached round for a few minutes near the end of the gale to E., and soon got back again to S.E., increasing to a hurricane. It terminated two hours and a quarter after this with strong breezes from E.S.E., and an hour after that the dense body of cloud began to break up," (page 38.)

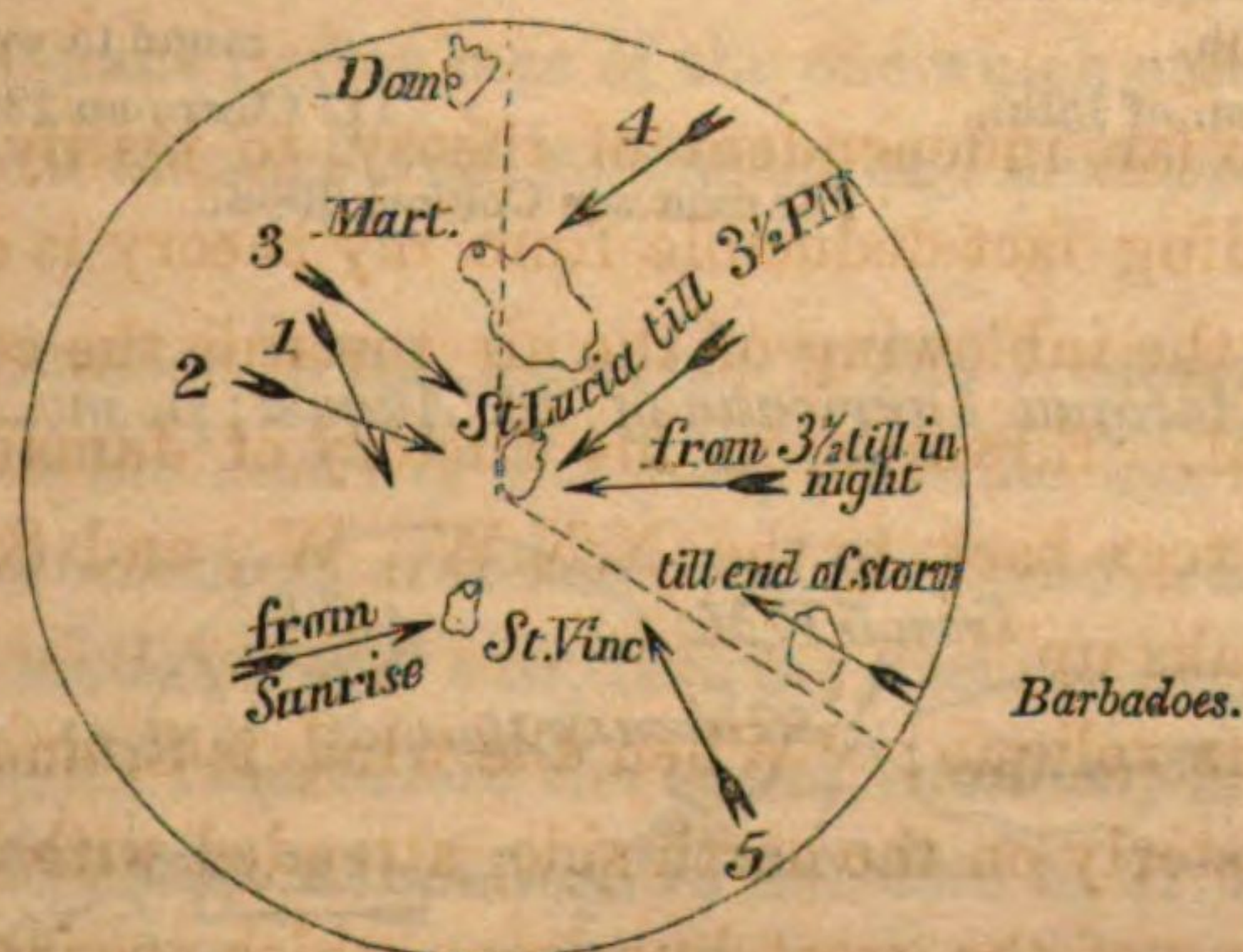
Luke Howard, in his second volume, gives an account of a hurricane in St. Lucia on the 21st October, 1818. "The wind is stated to *have set in N.W. at daybreak*, and raged with tremendous violence, with occasional falls of rain, until 3 p. m., when, *becoming southerly*, it abated, but did not immediately cease."

If the reader will examine the accounts given by Colonel Reid of the great Barbadoes hurricane of 1780, he will find that though the wind began to blow from the N.E., with some violence from the oblique force produced by the trade-winds, which, in this region, are known to blow all the year, yet it backed round to N.W. and blew for many hours with its greatest violence, and then changed back again by the E. to the S.E., beyond which it did not go.

Now, as the centre of this storm certainly passed within a few miles of the western side of this island, for it passed between Barbadoes and the ship Albemarle, which left Barbadoes during the storm, the facts furnished here are even more conclusive that the wind blew inwards to the centre of the storm, than if it had been merely stated that the wind commenced N.W. and terminated S.E.

If the reader has an opportunity of examining the chart I have made of this hurricane in "Phil. of Storms," I will be obliged to him if he will make the following corrections of a typographical mistake: for Amazon 2 p. m., read Amazon at 8 p. m., and for Chart . . . showing the course of the wind at 6 p. m., read Chart — . . showing course of the wind at 8 p. m. The chart is given here corrected.

Chart of the great Barbadoes hurricane, October 11, 1780, showing the course of the wind at 8 p. m.



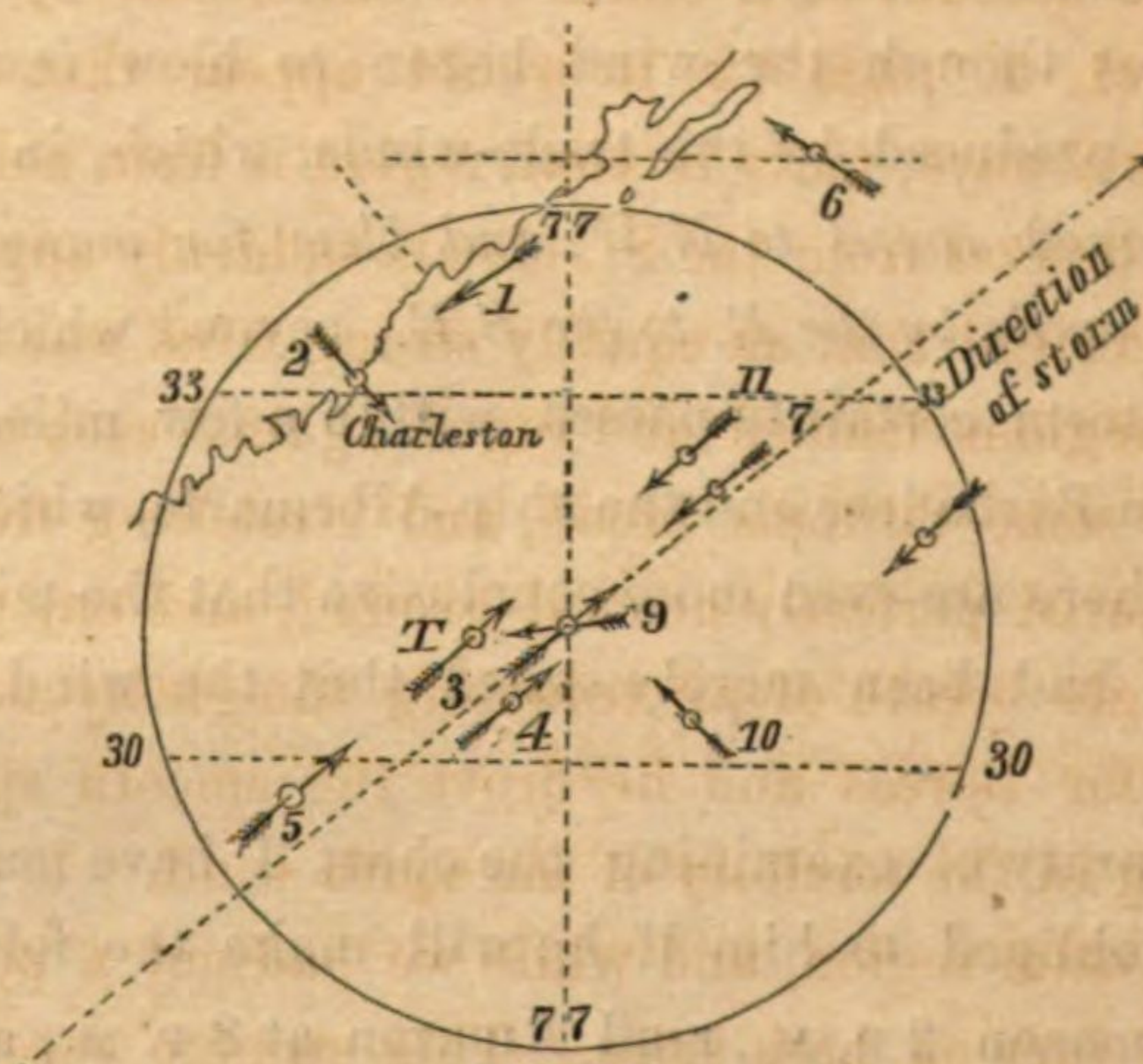
1. Montagu from 6 to 8 p. m.
2. Amazon at 8 p. m.
3. Alcine from 5 till 9 p. m.

4. Endymion from p. m. of 10th to 12th.
5. Albemarle from 4 1/2 p. m. till next day.

The dotted line is the course which the centre of the storm moved in.
For data see Colonel Reid

Much yet remains to be done to ascertain the shape that these great hurricanes assume when they reach the coast of the United States. Some of them certainly have then a diameter two or three, or even five, times greater from N.E. to S.W. than from S.E. to N.W., as the reader will see by examining my Philosophy of Storms, especially the hurricane of the 3d September, 1821, and the storm of the 18th August 1830. The hurricane of the 3d September, 1821, moved end foremost with its centre passing over Norfolk, between the capes of Delaware, and over New York, commencing everywhere in point with the wind northeasterly, and terminating with the wind southeasterly; and on the extreme southeast boundary the wind was everywhere from the southeast during the most violent part of the gale, and on the extreme northwest border the wind was from the N. and N.W. during its greatest violence. Charts of a few hurricanes are copied here, the data being furnished by Colonel Reid.

Position of storm at noon on the 18th of August 1837.

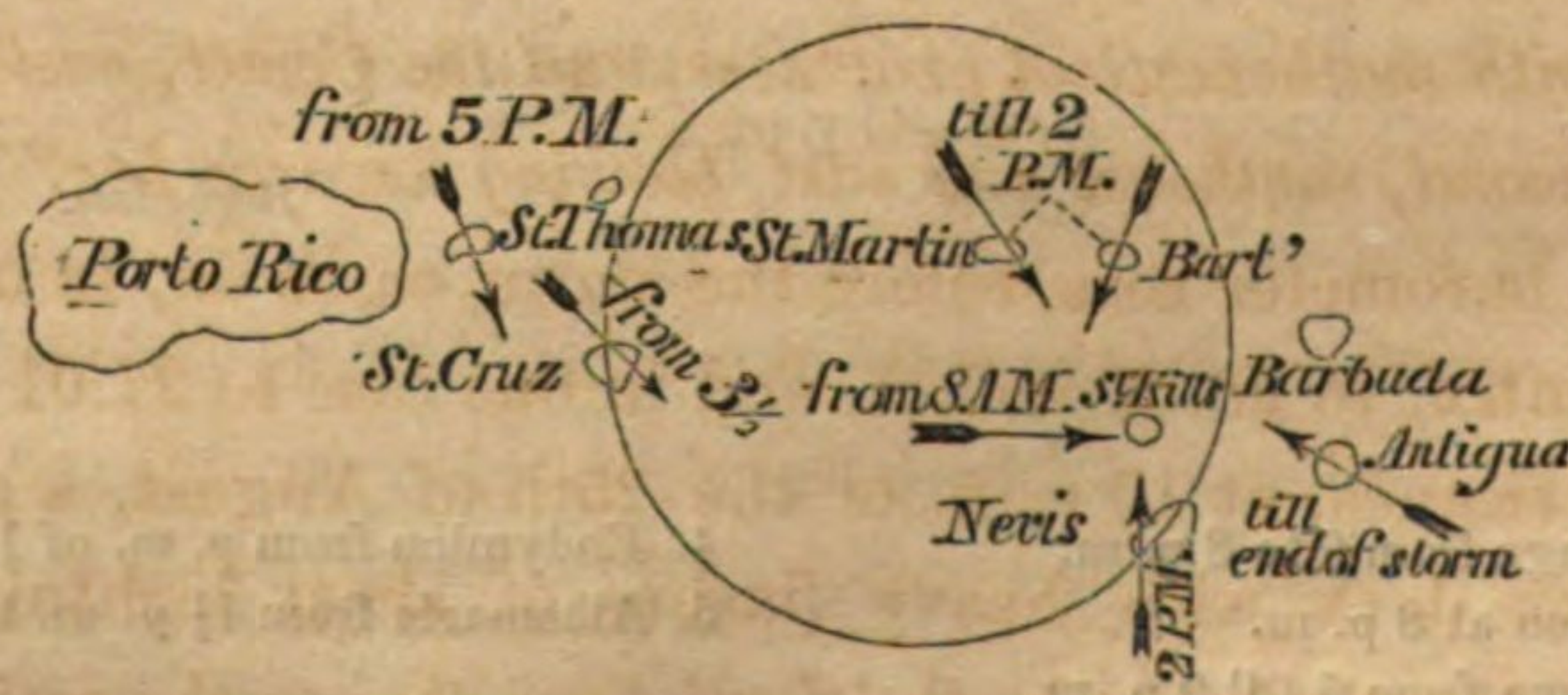


EXPLANATION OF ENGRAVING.

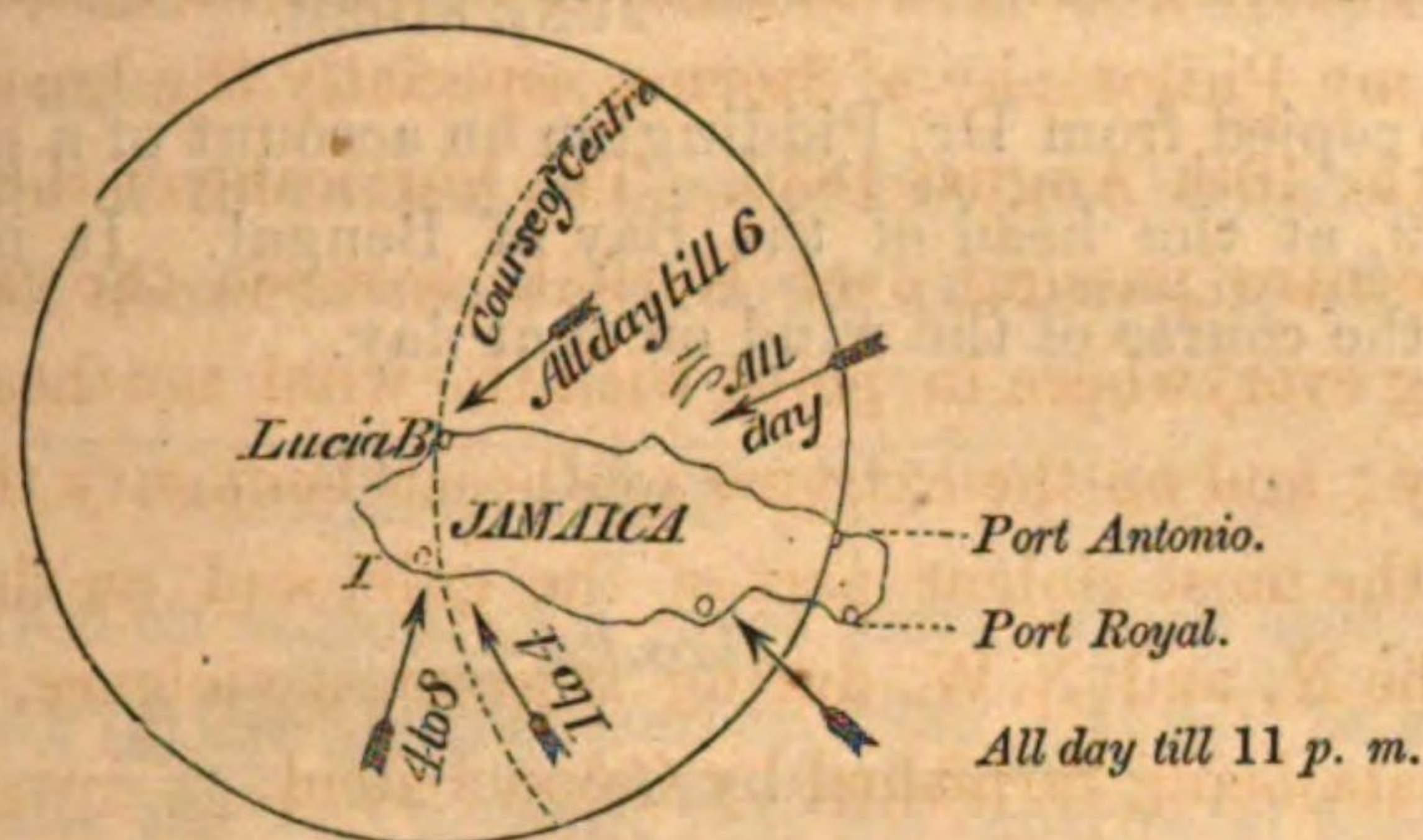
- | | |
|---|--|
| 1. Wind at Wilmington on p. m. of 18th. | 7. Vol. of till 8 p. m. of 18th. |
| 2. Oglethorpe on 18th. | 8. Westchester on 18th. |
| 3. West Indian all 18th from 2 a. m. | 9. Duke of Manchester till p. m. on 18th. |
| 4. Rawlins all 18th from 2 a. m. | 10. Delaware on 17th and probably on 18th, changing round to westward on 20th. |
| 5. Ida all day of 18th. | 11. Cicero on 18th. |
| 6. Penelope on p. m. of 18th. | |

For data see Colonel Reid.

Antigua hurricane of 2d August, p. m., 1837.



For data see Colonel Reid.

1. *Savannah la Mar, destroyed October 3, 1780.*

For data see Colonel Reid.

From the following graphic account of a storm off California, by Kotzebue, in his *New Voyage Round the World*, vol. 2. page 72, it would appear that the direction in which storms sometimes, and perhaps always, move in that region is from north to south. He says: "After a few days pretty fresh breezes from the S., clouds suddenly appeared in the N., and by the motion of the water, we perceived that an equally strong wind was rising in that direction. The waves from the opposite regions foamed and raged against each other like hostile forces, but between them lay a path some fathoms broad, and stretching from E. to W. to an immeasurable length, which appeared perfectly neutral ground, and enjoyed all the repose of the most profound peace, not a single breath of air troubling the glassy smoothness of its surface. After a time victory declared for Boreas and he drove the smooth space towards our vessel which had been hitherto sailing in the territory of the south wind.

"We presently entered the calm region, and while we had not a puff to swell our sails the wind raged with undiminished fury on both sides. This strange spectacle lasted for about a quarter of an hour, when the north wind, which had been continually advancing, reached us and carried us quickly forward towards the place of our destination."

49. In Maury's *Sailing Directions*, page 310, sixth edition, several hurricanes in the West Indies, and in the Atlantic along the coast of the United States, are investigated by Lieutenant B. S. Porter, U. S. Navy. Lieutenant Porter says of the one which occurred 26th August, 1848: "It follows, then, that the wind from the northeast, northwest, and southwest, blew towards the centre of the storm."

In the hurricane of the 2d October, 1852, he says: "*The Iconium, whose barometer is the lowest, 28.00 inches being taken as the centre of the gale, gives the wind at positions northeast of her, blowing towards her with mathematical exactness, and the Comet, east-southeast from her, has the wind on the first and second, southeast and east, blowing towards her.*"

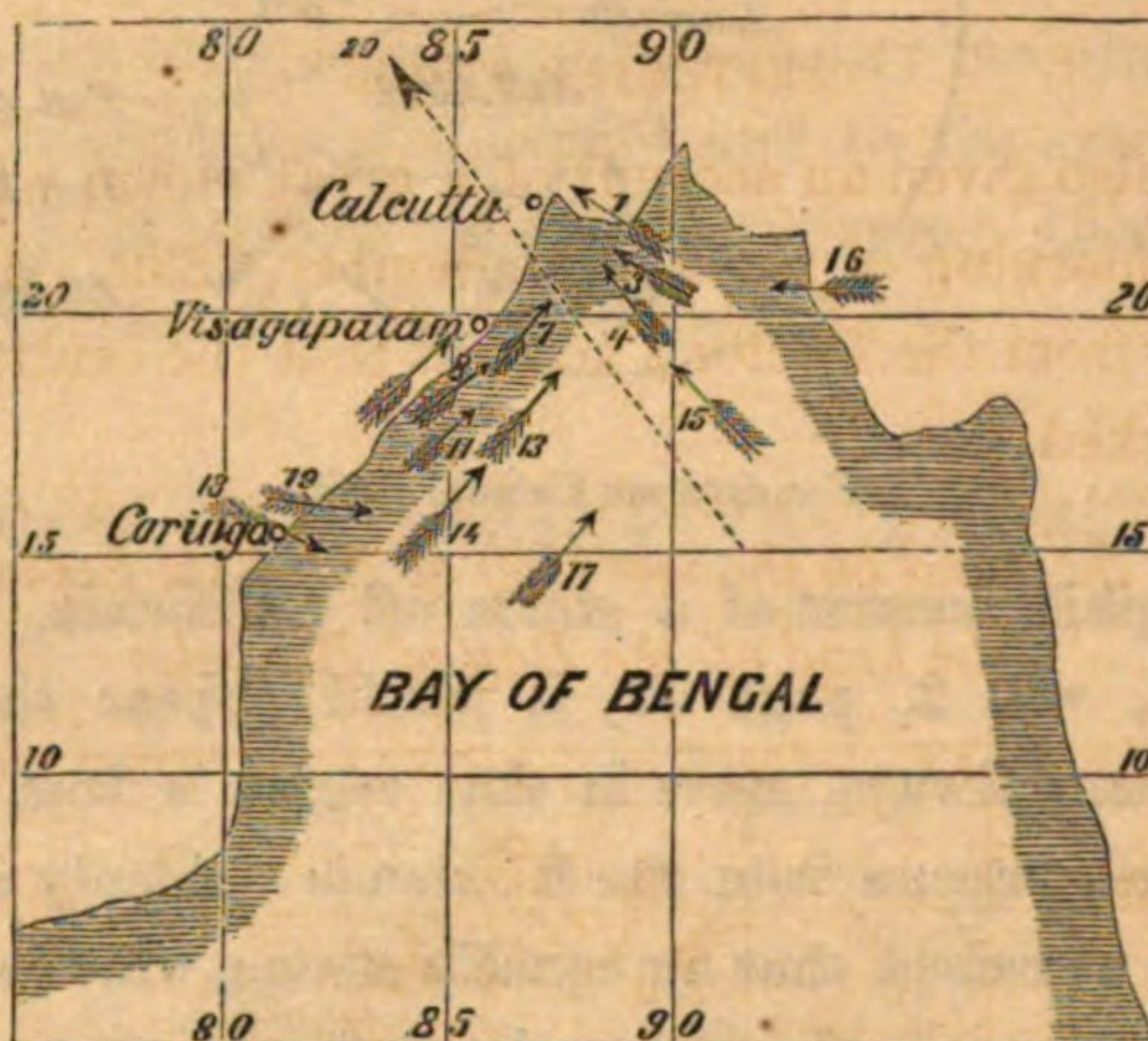
In these hurricanes the barometer rose before the storm came on, in one case to 30.50 inches and fell, when near the centre, to 28.00 inches, and in one case to 27.01 inches.

In the first of these hurricanes, at 10 P. M. of the 25th of August, a great part of the south and southwest sky became dark with heavy flashes of sheet lightning and heavy distant thunder, the wind blowing directly towards the cloud from the north-northeast; and at 5 P. M. of the 26th it broke away in the southern quarter, blowing a gale from the south-southwest. At

4 A. M. next day wind southeast. Last observation on 24th, latitude $23^{\circ} 41'$, longitude $73^{\circ} 12'$. This is the latitude in which the hurricanes move towards the north-northwest.

JUNE STORM.

67. I have also copied from Dr. Piddington an account of a great storm which occurred on the 5th of June, 1839, at the head of the Bay of Bengal. It is accompanied with a chart and arrows, showing the course of the wind on that day.



- No. 1. Calcutta, east-southeast, strong.
2. Diamond Harbor, east to south-southeast, strong with heavy rain; latitude $22^{\circ} 11'$; longitude $88^{\circ} 11'$.
3. Kedgree, same; latitude $21^{\circ} 52'$; longitude $87^{\circ} 59'$.
4. Hope, south-southeast, very hard all night of the 4th and day of the 5th; latitude $21^{\circ} 26'$; longitude $88^{\circ} 07'$.
5. Beacon, same as Diamond; latitude 21° ; longitude $88^{\circ} 27'$. Southeast and south-southeast blowing heavy, but more moderate than last night. [Not marked for want of room.]
6. Jane, same.
7. Amherst; latitude $20^{\circ} 03'$; longitude 87° . Perfect hurricane all night of 4th till 2 a. m., south to south-southwest then began to moderate; all day of 5th under foresail and close-reefed main-topsail, with rain.
8. Krishna; latitude $19^{\circ} 40'$; longitude $86^{\circ} 27'$. Dead calm at 1 p. m., and wind suddenly veered round from north and northwest to southwest and blew a furious gale, moderating at 6 next morning.
9. Juggernaut Pagoda; latitude $19^{\circ} 48'$; longitude $85^{\circ} 48'$. Gale north on 4th, on 5th southwest.
10. Mary Somerville, 18 miles southwest half west from above. Strong gale southwest increasing to a severe gale south, being then 15 miles south of east from above. On the 4th fresh gales west, with heavy rain.
11. Justina; latitude $18^{\circ} 15'$; longitude $85^{\circ} 11'$. On the 5th, southwest, moderate; very severe on the 4th p. m., southwest by south; on 4th west-southwest; severe gale veering to southwest, p. m.
12. Ann Lockeby, same as Amherst all night of 4th and 5th till 4 p. m., with heavy rains.
13. Eden; latitude $18^{\circ} 01'$; longitude $88^{\circ} 52'$. Hurricane west-southwest all night of the 4th and 5th till 4 p. m., with heavy rain.
14. Mobile; latitude $16^{\circ} 20'$; longitude $85^{\circ} 20'$; southwest, veering to south-southwest; more moderate rain in p. m.
15. J. W. Dare; latitude $18^{\circ} 44'$; longitude $93^{\circ} 50'$; southeast on 5th; smart breezes on night of 2d and morning of 3d; heavy gale from south-southeast. The gale was then at its height, having begun about noon of 2d. It reached the Krishna at 1 p. m. of 5th, with its centre.
16. Akyab; latitude $20^{\circ} 05'$; longitude $92^{\circ} 50'$; east gales, with rain for twenty-four hours.
17. Lady Macnaughten; latitude $14^{\circ} 51'$; longitude $88^{\circ} 16'$; on 4th and 5th, west by south to southwest by south; very severe gale; moderating on 5th.
18. Masulipatam, west-northwest; blowing very fresh on 4th and 5th.
19. Laurel Amelia; latitude $17^{\circ} 22'$; longitude $83^{\circ} 44'$; on 5th, westward, a hurricane; on 4th, west, hard gales; latitude $16^{\circ} 56'$; longitude $82^{\circ} 58'$.
20. Direction of centre of the storm.

This storm was of great length from southeast to northwest, for its southeast border had hardly left the J. W. Dare, on the morning of the 4th, when its northwest border had reached Chuprath, latitude $25^{\circ} 40'$, longitude $84^{\circ} 40'$. How great its diameter in the other direction is

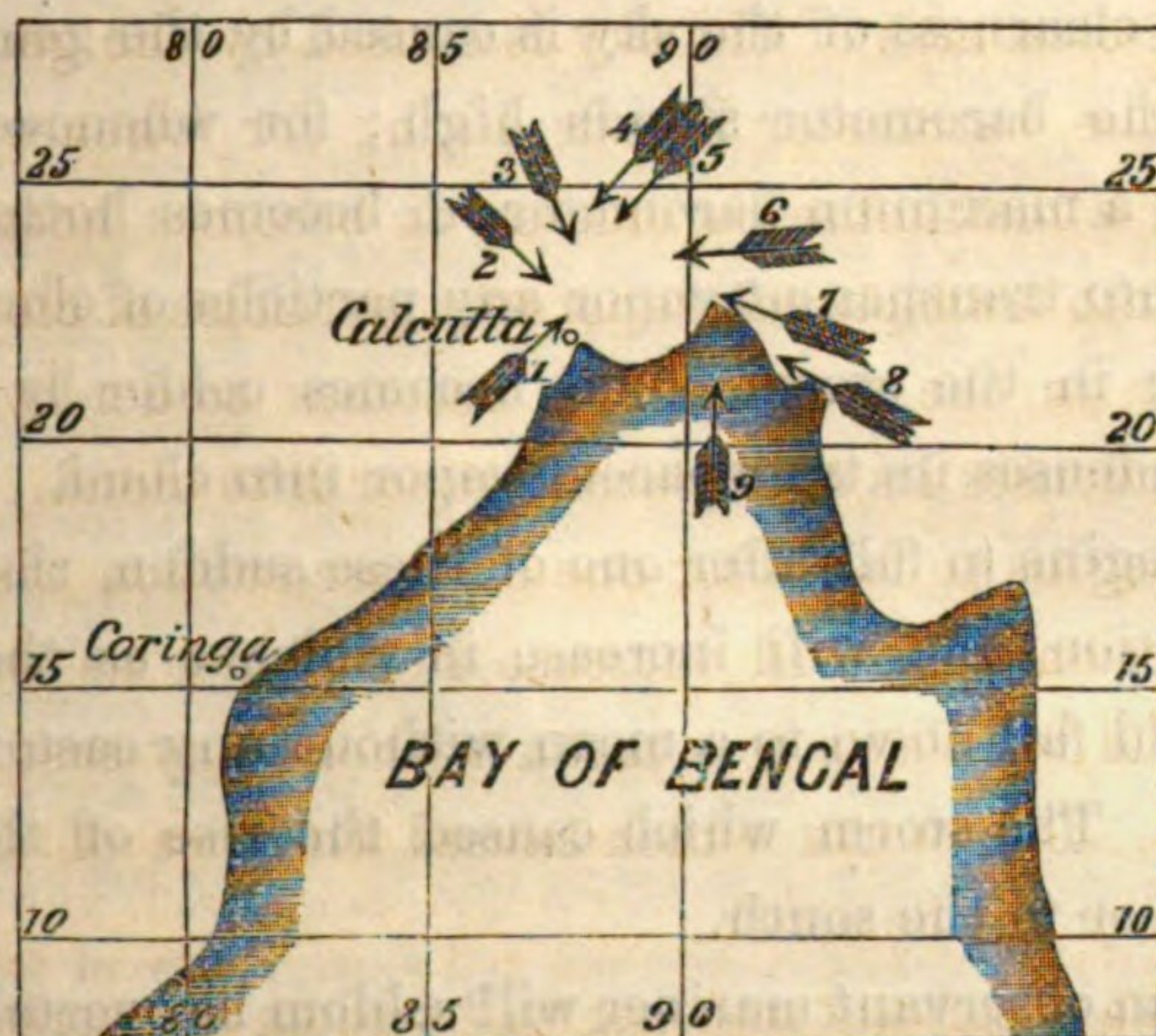
not known. But one thing is certain, that all the winds on the northeast side were from eastward or southeastward; and all the winds on the southwest side were from the southwestward, as far as known, after the centre of the storm passed, with the exception of No. 18 and 19, at a great distance from the centre.

Dr. Piddington makes the centre of this storm at noon of the 5th, latitude $19^{\circ} 25'$, longitude $87^{\circ} 1'$. He seems to think that all these storms were round, as I suppose all must who believe in the centrifugal doctrine.

SEPTEMBER STORM.

68. Dr. Piddington has also given an account of a great storm which occurred at the head of the Bay of Bengal, on the morning of the 21st September, 1839. It will be seen by the accompanying chart and extracts from the Doctor's account that the centripetal tendency of the wind in this storm was quite marked.

Chart showing the course of the wind on the morning of the 21st September, 1839, in the storm at the head of the Bay of Bengal.



1. Calcutta, southwest at 5 A. M., squalls and rain; wind changed from northwest after midnight, with heavy gusts and rain.
2. Moorshedabad, northwest all day, with tremendous gusts of wind and rain. This station is about 90 or 100 miles north of Calcutta.
3. Maldah, north to northwest all night of 20th and day of 21st till 3 P. M., abating gradually till 10½.
4. Rungypore, at 10.30 A. M. of 20th, a storm commenced northeast, and continued till 1 A. M. of 21st, but increased again; until from 8 to 10 A. M. it blew very hard between north and northeast.
5. Chilakhal, wind northeast all day 20th and 21st.
6. Jamalpore, wind east on 21st, varying a little south of east; severe all night of 20th, diminishing all next day; heavy rain.
7. Dacca, southeast; hard, with heavy rain at 3 A. M. of 21st, with heavy squalls till 6 A. M., when the rain ceased.
8. Comilla, southeast by south all night of 20th and morning of 21st; heavy showers of rain.
9. Burrisaul, very violent southeast till after midnight of 20th, then settled south, changing to west on morning of 21st.

I have examined many other of Reid's hurricanes, and I find that the wind in all of them blew in towards the centre; and the only reason that Colonel Reid did not discover this fact is that he did not draw arrows showing the course of the wind at some one particular moment.

I gave before the data of one of Mr. Thom's storms at No. 16, from which it appears clearly the wind blew exactly in towards a common centre while the hurricane was passing over Mauritius.

It will be in vain, however, to attempt to avoid the *great winter storms* in the Atlantic; for a single storm extends from Newfoundland to Bermuda, and perhaps much further from north to south, and moves side-foremost towards the east or south of east. Ships coming to this country from Europe will meet more storms than ships going in the opposite direction, but they will not be so long in any one of them; and, from what has been said about the direction in which they move, the mariner will know how to sail to be in a storm as short a time as possible. He will also know when the violence of the gale is over, so as to use the wind in the tail of the storm to the best advantage. In case the mariner is in any of the ports on our eastern coast, or in any of the western ports of Europe, he will generally be able to judge whether it will be safe to set sail or not, and get off the coast before a storm comes on. The barometer begins to rise from forty-eight to fifty-six hours before the storm comes on, most generally with an increase of temperature, and a clear, calm day. This rise of the barometer is caused by the outspreading of the air above from the region of the storm, expanded there by the latent caloric evolved by condensation of the vapor into cloud; and the rise of temperature is caused by the radiation downwards of the heat of this upper air, just protruded out from the storm cloud, with this latent caloric in it; and the clearness of the sky is caused by the gentle downward motion of the air in the region where the barometer stands high; for whenever a column of air moves downwards, as it must under a maximum barometer, it becomes hotter by increasing pressure, and thus is able to dissolve into transparent vapor any particles of cloud it may contain, just as, conversely, the column of air in the storm cloud becomes colder by diminished pressure as it moves upwards, and thus condenses its transparent vapor into cloud.

Soon after the barometer begins to fall after one of these sudden rises the wind will begin to blow from some eastern direction, and will increase in violence as the storm approaches. If, however, the barometer should fall down to a mean without any eastern wind, then *no storm of any violence may be expected*. The storm which caused the rise of the barometer in this case has passed away to the north or to the south.

150. *As to sudden squalls*, an observant mariner will seldom be overtaken by one unforewarned. I will only say, that the sudden and violent squalls are produced by the outspreading of the air below on all sides from a falling shower. The cooling effects of the drops of water (descending from a great height where they are sometimes congealed) on the air below, thus increasing its specific gravity, and also the impulse they impart to the air by their motion downwards, are the causes of this outward motion of the air in front of the descending shower.*

This squall cloud, with its rain, is always in sight before the squall comes on, long enough to prepare for its violence. On the approach of the cloud not unfrequently a moderate breeze will be perceived blowing towards the cloud; that is, in an opposite direction to what it will be when the violent squall comes on.

In the latitudes of Pennsylvania and Maryland these squalls nearly always come up from the west or northwest, moving side-foremost, and it is probable that the same will be found to be the case in the Atlantic within the same latitudes.

The squall cloud may be distinguished from all others whilst it is yet a considerable distance,

* Many instances are given in the books where a wind blows outwards from the base of a mountain while it is raining, when at the same time the air above with the clouds is moving in an opposite direction towards the mountain. This is of the nature of a squall.

ten or fifteen miles, from the observer. It is always extremely dark at and near the horizon, being thinner and lighter in its upper parts as they approach the zenith.

This thin part is the outer rim of the cloud, thrust outwards above by the great expansion of the air in the formation of the cloud itself; and though it appears higher to the observer, it is in reality on a level with the upper part of that portion of the cloud out of which the rain is pouring. Just in front of the falling rain, and under the rim, which is now approaching the zenith, long rolls of dull whitish clouds appear, which would appear white if not shaded by the upper cloud, and when these clouds reach nearly to the zenith the squall will come on nearly at the same time with the rain.

These low clouds are constantly forming in their front by the upward motion of the air there, as fast as their hinder parts are swept down by the falling rain, and thus they appear constantly just in front of the squall, for it is only in front of the squall that there is an up-moving column of air below.

If these low rolls of parasitic clouds should not appear, or if there is no rain seen to fall behind them, or, especially, if the darkness of the principal cloud does not reach the horizon, but glimmerings of light are seen below it, *then a violent squall need not be feared*. The rain, in this case, is not heavy enough to push out the air below with dangerous violence. Where the air is not pushed out below no parasitic clouds can be formed, for it is from this air cooled by the falling rain, and swept back in part by the air which is blowing in towards the cloud, that the parasitic clouds are formed.

I have described these squalls as they appear on land, but I think the phenomena will be found to be nearly the same at sea, especially the darkness of the cloud below, near the horizon, which perhaps will be increased by the spray of the waves.

Whether the squalls between Europe and the United States can be avoided, as the hurricanes of the tropical seas can, I cannot say. If the cloud appears of indefinite extent on its approach, it will be in vain to attempt to sail round it; for the velocity of these squalls in the Atlantic in high latitudes is much greater than that of the hurricanes of the West Indies, or of the typhoons of the bay of Bengal; and their approach cannot be predicted by the barometer. If, however, the mariner shall perceive that the middle of the squall-cloud is not about to pass over him, it might be well to recede as far as possible from its most gloomy looking part when very great violence is apprehended.

151. Are not the pamperoes of the southeastern coast of South America, in the neighborhood of Buenos Ayres, of the nature of these squalls, produced by falling rain behind them? They are described as coming from the west over the plains of the interior, and raising an immense cloud of dust before them. If this cloud of dust is succeeded by a violent fall of rain, with all the phenomena of the squall-cloud preceding, the true explanation of the pampero is the same as that of the squalls just given.

152. So, also, if the *northers* in the Gulf of Mexico have the squall-cloud behind them, with a fall of rain accompanying them, these *northers* may be accounted for in the same way as squalls, with the additional circumstance of a cold land-wind to increase and prolong their violence, *i. e.*, cold compared with the temperature of the Gulf of Mexico. And if it shall be found by future observation that great rains take place on the isthmus of Tehuantepec, south of these *northers*, at the same time that the *northers* prevail, then will the violence of the norther be

increased by *aspiration*, for the barometer in the region of the rain towards which the wind blows will be below the mean.

153. So on the western coast of Africa, what is improperly called "the tornadoes" will come under the laws of squalls.

"From north latitude five to fifteen, these storms appear at certain seasons almost every day.

"First, a cloud is seen to rise in the east, and become blacker and blacker as it approaches. Finally all the eastern sky and zenith are enveloped in profound night, which contrasts with the purity of the sky in the west.

"Immediately before the hurricane breaks loose, a slight and almost insensible breeze blows from the west towards the approaching cloud, or the air is entirely calm. Then comes on a furious wind, with rain from the east, and generally lasts from twenty minutes to half an hour."—(Kaemtz.)

"The African tornado is merely an ordinary thunder-gust, which seldom has power to blow down a tree or unroof a thatched house. This wind usually comes from the northeast, and the cloud in which it occurs moves directly to meet the southwest breeze. When the two contrary winds meet there is a short calm, which is followed by the wind and rain from the thunder-cloud."—(Bowen's Central Africa, page 233.)

All these phenomena need no further explanation. I will add, however, that the direction in which storm-clouds move near the equator is towards the west, because the current of air there, both above and below, is towards the west. Captain Wilkes was twenty-three days crossing the belt of rains in the Atlantic, from 12° to 4° north latitude, and during all that time the upper clouds moved from the east. On each side of that belt the wind below moved towards the belt, and in the belt itself there was but little wind.—(Introduction, page 11.) And in south latitude 3° , near the middle of the Pacific, after a very heavy fall of rain, 5.2 inches, the temperature of which was 62° , air 70° , the upper stratum of clouds after it ceased was moving from east-northeast.

In the southern hemisphere it is probable that storms follow the same laws as in the northern, except that when the direction in which they move is stated, the word south must be substituted for north, and north for south; the words east and west remaining the same.

Such is the case, so far as the very limited examination of southern storms has been made, especially by Mr. Thom; and that such is really the case is clearly indicated by the theory.

154. In regions where it rains almost every day, and all day, as in a belt a few degrees north of the equator, in the Atlantic, during the summer, the barometer will stand below the mean without much fluctuation or violence of the wind; and on each side of this belt, as Maury has shown, the wind will blow with considerable uniformity towards the rainy region, from the northeast on the northern side, and from the south or southwest on the southern side; and, of course, there must be an up-moving current in the region of the rain.

155. This up-moving current must come under less and less pressure as it ascends, and therefore expand and grow colder by expansion, and thus condense its vapor into cloud and give out its latent caloric, which will expand the air still more, causing it to spread out above, overlapping the air in the region of the trade winds, causing *the barometer to stand above the mean, most of all on the outer border of the trade winds, as it is known to do*. Moreover, any up-moving columns of air, in the regular trades, if any occur, cannot produce rains; because, first, the

upper current of air moving in a direction almost opposite to the lower current, the up-moving current, if it should rise high enough to penetrate the upper current moving towards the north-east, would be broken in two, and any cloud which might begin to form would be dispersed; and, second, the upper current coming from the region of the rain, and containing some of the caloric given out by the condensing vapor in the formation of cloud, the up-moving current on reaching this overlapping current, warmer, and of course specifically lighter than itself, would not swim in it, but spread out in all directions between the upper and lower currents, and thus a cloud sufficiently lofty to produce rain could not be formed.

At the outer borders of the trade winds the up-moving columns may produce rains: first, because *there* the cross currents have nearly ceased; and second, because the upper current will have radiated away much, or perhaps all, of its superabundant caloric by the time it reaches the borders of the trades, and there, in and beyond these borders, the mariner will be liable to meet with squalls in the borders of up-moving columns forming lofty clouds.

It is true that, at the outer borders of the trade winds, where the barometer stands all the year considerably above the mean of the latitudes just north and south of these borders, there is a general sinking down of the atmosphere, as *there must be* wherever the barometer stands higher than in surrounding regions in their vicinity; nevertheless, this downward motion will not prevent columns of heated air from rising and forming clouds, as explained before; for, as soon as the upper parts of the atmosphere become so cold by radiation as to contain less caloric for a given weight than the air near the surface of the earth or sea, the upper air will aid the up-moving columns to ascend through it, while it sinks down itself by its superior specific gravity to take the place of the up-moving air. Wherever there is an ascending column there will be cloud, *and all around it where the air is descending it will be perfectly clear*. There must, however, be much more air descending than ascending in these regions at the outer borders of the trade winds, for the *trade winds which blow from these borders towards the equator must be furnished from the downward currents on these borders*.

There cannot be any widely extended storms in the outer borders of the trade winds, for the whole mass of the air cannot ascend where the barometer stands higher than it does in surrounding regions; the rains and winds accompanying them will, therefore, all be from clouds of small horizontal diameter, which, in case of threatened violence, can all be avoided by the mariner, if he follows the rules before laid down concerning hurricanes and squalls.

It is important, however, to mention that, from the investigations of Redfield and Reid, it is known that the hurricanes of the West Indies, in moving from latitude 20° to latitude 30° , gradually change round in their motion from N.N.W. to N. and N.N.E.; and, of course, according to the theory explained above, the wind, in case of hurricanes, will set in more and more northerly and northeasterly as they advance to these higher latitudes in the localities over which their centre is about to pass. It follows, then, from what was said before, that *if the wind becomes very strong from about north on the approach of a hurricane, the mariner may sail either east or west to avoid running into the centre of the storm; but if the wind sets in strong from about northeast, he must sail to the southeast; and if the wind sets in from near the northwest, he must sail to the west or southwest*.

156. In the hurricane the wind always blows towards the cloud below, continuing to increase in the same direction after the rain begins; but in the squall, though the wind sometimes

blows gently towards the approaching cloud, it never becomes very strong in that direction, and generally dies nearly away when the rain beyond the parasitic cloud comes in sight. Besides, these parasitic low rolls of cloud, before described as belonging to the squall cloud, *never appear under the rim of the hurricane cloud*; whenever low clouds appear under the rim of the hurricane cloud, they always are seen in the form of scud moving rapidly towards the centre of the great hurricane cloud, where they unite with its base and ascend there with the ascending current, where the barometer stands very low.

157. If, unfortunately, the sailor should be driven far into the interior of the hurricane, where the barometer sometimes sinks from one and a half to two inches, and even more, he will be enveloped in a thick cloud; for the air will cool by expansion, from the diminished pressure of two inches of mercury, about eight degrees of Fahrenheit, which, in most cases, will bring it below the dew-point in the borders of the torrid zone, and thus *the base of the cloud will reach the sea*.

In these hurricanes and typhoons, especially near their centre, the up-moving current of air is so rapid as to carry drops of rain upwards after they are formed in the cloud, until they accumulate in such quantities as to force their way downwards with most dangerous violence. These falling masses of water will have a tendency to push the air outward on all sides from under them in their fall, on the principle of the squall, before explained, and, of course, they will increase the violence of the wind of the hurricane on their side next the centre of the hurricane, and diminish its violence on their side opposite to that centre; and *thus will be formed those heavy and irresistible gusts* that are frequently experienced during the continuance of the hurricane; these are not felt where the rain is uniform; at least so says the theory.

158. In the region of the trade winds, where the four diurnal fluctuations of the barometer are never interrupted except by the proximity of a storm, a sudden rise of the barometer, even a quarter of an inch, may be taken as *a certain proof that a storm is not very far distant*. If no storm cloud is yet visible, even near the horizon, watch all the phenomena; and if the barometer should fall again pretty soon to near the mean without either a storm cloud appearing, or the regular trade wind changing its course or strength, then has the storm occasioning the rise of the barometer passed the observer, and nothing need be feared.

159. The great depression of the barometer below the mean, almost constantly about Cape Horn and in high south latitudes, is no doubt caused by the great and frequent rains and snows which are known to occur there, for wherever they occur latent caloric must be given out. I have suggested a hypothetical cause for these rains and snows in my third report on meteorology to the Secretary of the Navy, to which I refer.—(See No. 95.) If it shall be found, by future observations, that the barometer stands above the mean, without snow or rain, in higher south latitudes than navigators have yet reached, then the cause I have suggested is probably the true one; but if the barometer stands below the mean there, then will the hypothetical explanation fail, as many other hypotheses have done before.

160. At present I consider it premature to lay down rules to guide the mariner in storms in these high southern latitudes. I will merely say, if the theory of storms is true, as laid down in my Philosophy of Storms, and in my second and third reports on meteorology to the Secretary of the Navy, it cannot fail to throw a flood of light on the parts of this interesting science which have hitherto remained in obscurity.

161. I am fully aware that the above rules, for the guidance of the mariner on the approach of storms, are very imperfect. Every science is imperfect at its commencement; and the theory from which these rules have been deduced is only about twenty years old.

The science of astronomy has been brought to its present advanced state only by the combined efforts of hundreds of observers for centuries; and, with the aid of all the commanders of vessels into whose hands these rules may fall, meteorology, so far as storms are concerned, will, in time, take its rank among the *exact sciences*.

162. I cannot doubt that every intelligent man, who shall read with care the above reports, will be satisfied that the theory from which the "rules" are deduced is founded on well established physical principles; that it is strongly corroborated by the experiments with the double nephoscope, detailed above in the third report; and that it affords at least a plausible explanation of a great variety of meteorological phenomena never heretofore explained.

Such being the case, I earnestly request the commanders of American vessels, and others, to keep journals of the weather at sea and in port, and transmit them to the Navy Department, that they may be used hereafter in rendering more perfect the rules intended for their use. In hopes that this request will not be unregarded, I will here add a few remarks to assist you in your observations.

First. It is of great importance to know the quantity of vapor in the air; for it is from the latent caloric contained in the vapor that all the force of the wind in storms is derived.

163. It is only when the dew-point is high that there is sufficient steam power in the air to produce a violent storm; for *all storms are produced by steam power*.

The dew-point is the *highest temperature* at which the moisture in the air will condense on any cold body, and may be ascertained by taking a bright, thin metallic tumbler, with water in it, and cooling that water down by means of ice, or muriate of ammonia and nitrate of potash in powder, just to the point where the vapor in the air begins to condense on the outside of it; then, by thrusting a thermometer into the water, this temperature is ascertained.

The quantity of vapor in the air, when compared to the air itself in weight, is greater the higher the dew-point is, as will be seen by the following table, which I have calculated from the experiments of the illustrious John Dalton, of Manchester.

This is the table I used in calculating the specific caloric of air in my third report.

164.—TABLE OF DEW-POINTS AND RELATIVE WEIGHT OF VAPOR IN AIR.

Temperature of dew-point.	Elastic force of vapor in inches.	Weight of vapor in parts of air.	Temperature of dew-point.	Elastic force of vapor in inches.	Weight of vapor in parts of air.
32°	0.200	$\frac{1}{5}$	57°	0.474	$\frac{1}{10}$
33	.207	$\frac{1}{48}$	58	.490	$\frac{1}{97}$
34	.214	$\frac{1}{44}$	59	.507	$\frac{1}{94}$
35	.221	$\frac{1}{40}$	60	.524	$\frac{1}{91}$
36	.229	$\frac{1}{36}$	61	.542	$\frac{1}{88}$
37	.237	$\frac{1}{32}$	62	.560	$\frac{1}{85}$
38	.245	$\frac{1}{28}$	63	.578	$\frac{1}{83}$
39	.254	$\frac{1}{25}$	64	.597	$\frac{1}{80}$
40	.263	$\frac{1}{22}$	65	.616	$\frac{1}{77}$
41	.273	$\frac{1}{19}$	66	.636	$\frac{1}{75}$
42	.283	$\frac{1}{17}$	67	.655	$\frac{1}{73}$
43	.294	$\frac{1}{16}$	68	.676	$\frac{1}{71}$
44	.305	$\frac{1}{15}$	69	.698	$\frac{1}{68}$
45	.316	$\frac{1}{14}$	70	.721	$\frac{1}{66}$
46	.328	$\frac{1}{13}$	71	.745	$\frac{1}{64}$
47	.339	$\frac{1}{12}$	72	.775	$\frac{1}{62}$
48	.351	$\frac{1}{11}$	73	.796	$\frac{1}{60}$
49	.363	$\frac{1}{10}$	74	.823	$\frac{1}{58}$
50	.375	$\frac{1}{9}$	75	.854	$\frac{1}{56}$
51	.388	$\frac{1}{8}$	76	.880	$\frac{1}{54}$
52	.401	$\frac{1}{7}$	77	.910	$\frac{1}{52}$
53	.415	$\frac{1}{6}$	78	.940	$\frac{1}{51}$
54	.429	$\frac{1}{5}$	79	.971	$\frac{1}{49}$
55	.443	$\frac{1}{4}$	80	1.000	$\frac{1}{48}$
56	.458	$\frac{1}{4}$			

By the above table it will be seen that there is twice as much vapor in the air when the dew-point is 52° as there is when the dew-point is 32°, and that the quantity is doubled again when the dew-point is 73°. And so it would be doubled again if the dew-point should be raised artificially to 95°; for it seldom exceeds 80° in the open air even in the torrid zone.

165. But a more simple way of finding the dew-point, and (as I have ascertained by very numerous experiments) quite as accurate, is by means of the wet bulb thermometer, in the following manner, the formula for which is given in No. 117: First, take the temperature of the air in the shade where it is not exposed to radiation from bodies heated by the sun; then cover the bulb of the thermometer with a thin wet rag or bibulous paper, and swing it pretty rapidly in the air, until it sinks as low as it will below the temperature of the air, by the cold of evaporation, which will be greater as the air is drier; now subtract the wet bulb temperature from the temperature of the air, and take the remainder and multiply it by 103—a number which I found by experiment—and, after multiplying by 103, take the product and divide it by the wet bulb temperature, and, when you subtract the quotient obtained by this division from the temperature of the air, the remainder is the temperature of the dew-point—which you will find to be the case, if you take the dew-point directly with the metallic tumbler, as before

directed. In case the temperature of the air is below the freezing point, the wet bulb must be covered with a film of ice entirely frozen; and then I find by experiment that evaporation from the ice is such as to correspond with the rule given above for the wet bulb, at least as low as 20° Fahrenheit.—(See my *Philosophy of Storms*, page 150.) The dew-points in the table at No. 118, are calculated from the temperature of the air and the wet-bulb temperature there given; and by calculating some of those dew-points according to the rule here given, which is the same as the formula there laid down, the reader can satisfy himself that he understands the rule, if his result agrees with mine.

166. The intelligent mariner will see the importance of having many observations of the dew-point in connexion with the temperature of the water and air in and on each side of the borders of the trade winds, and also in connexion with the pressure of the air, as indicated by the barometer. It is only by a great number of such observations that the true law of the dew-point in this belt can be known and established. Meteorologists at present believe that the dew-point is, as a general rule, higher, the lower the latitude is. I think it will be found to be lower in the belt of high barometer near latitude 30° than it is some degrees further north in the northern hemisphere, and further south in the southern hemisphere; and wherever the middle of the belt of high barometer will be found to be, there, I think, will be found also the lowest dew-point. And especially round the borders of rains, I think, it will be found that the dew-point is very low. I would observe, also, that the value of observations on this point will be much increased by their frequency—once an hour, or at least once in two hours.

167. It is also a matter of high importance to note the direction in which squalls come up, especially in this belt of high barometer about latitude 30° , and some degrees on each side of it. According to my theory, storm clouds ought to move towards the east, or south of east, in latitudes from 35° to 55° ; and in low latitudes, near the equator, they ought to move towards the west; but in the borders of the trade winds, my theory is at present not able to predict in what direction storm clouds in general ought to move. I have shown, in the third report, that the air comes down from the upper regions to the surface of the sea in the borders of the trade winds; and therefore, in the upper parts of the atmosphere, the air must come from the southward on the south side of the belt of high barometer, and on the north side of this belt it must come from the northward, in the upper regions; otherwise the descending current in the belt of high barometer could not be supplied with air to descend and blow out both ways below, as it was shown before to do. The direction of the upper current of air may be always known by the cirrus cloud—that thin, hairy cloud—which is always many miles high.

It is probable that storm clouds move in the direction of the cirrus in this belt, as they do in other latitudes.

168. I have observed that when the dew-point is 20° and more below the temperature of the air in the latitude of Washington and Philadelphia, it not only never rains, but hardly ever do clouds of any considerable magnitude form. On such days the columns of ascending air have to reach twenty hundred yards high and more before they begin to form cloud by the cold of expansion from diminished pressure; and it is seldom that currents can reach that height without being leaned out of the perpendicular motion upwards; and, though clumps of air sometimes reach that height, and form cloud, yet, there being no constant supply from beneath, a cloud of great size cannot form. Such clouds never appear with a flat, dark base, but they are always

ragged and ill-defined, and, generally, soon evaporate entirely, as, indeed, all clouds do, sooner or later, that have no ascending current of air under them, as was explained in No. 51. It would be highly interesting to observe whether it ever rains in *the belt of high barometer* when the dew-point is more than 20° below the temperature of the air.

169. By watching the manner in which the cumuli form in the morning, when they first begin to make their appearance, it may frequently be known whether there will be rain or not during the day.

If the cumuli form with well-defined borders and flat, dark bases, and do not lean much out of the perpendicular, this is a favorable symptom for rain during the day; and if they constantly increase in size, and especially if they form over their tops that thin film of cloud described and explained as to its formation in No. 46, it then hardly ever fails to rain during some time of the day—if not where the observer is, at least within the reach of his vision. This rule applies only to the warm seasons.

I think the mariner will be richly rewarded by observing these phenomena and their results at sea, and noting them under the head of “remarks.”

170. There is another phenomena which I will mention, more on account of its beauty than from any practical utility which can be derived from it at present, namely: the western part of the sky in the latitude of Washington will sometimes appear entirely covered with cloud for hours together, and the eastern part of the sky entirely clear, and that, too, when all the clouds in the zenith, and as far west as the eye can reach, are in motion towards the east. Last evening (June 9, 1851) this phenomenon occurred. I watched it constantly every few minutes from 8 o'clock till 11, and the clouds which were in motion towards the east never reached beyond about forty-five degrees east of the zenith; in fact they appeared to reach a certain boundary, and there disappear. They did not appear to stop at this boundary and accumulate there, but, on the contrary, their most eastern boundary was the thinnest.

The barometer at this time, I observed, was beginning to rise, and there is no doubt that there was a downward motion of the air in the region where these clouds constantly disappeared as soon as they reached it from the west; and the downward motion of air in which cloud exists will cause the cloud to evaporate, as explained before in No. 84.

Had the clouds thus dissolving been that lofty cloud called cirrus, (*which is always formed out of the top of the rain cloud*, and never, as far as I have seen, out of any other,) then I should have inferred that there was at that very time a great storm of rain in the west, and that we were in its borders, where even a slight rise of the barometer indicates a downward motion of the air, and of course a dissolution of any cloud that the descending air may have in it at the time; but the clouds were not cirrus, and, therefore, no such inference could be drawn from the phenomenon. All that can be said on the subject, then, is, that the downward motion of the air, in which these clouds were constantly dissolving, was produced by the outspreading of the air from the top of a storm cloud, too far off to send its cirrus, or rim of the storm cloud, to the place of observation.

171. I mentioned before that a sudden rise of the barometer, especially in low latitudes, is a proof that there is a storm in the neighborhood, and is one of the first indications of an approaching storm.

If the reader will turn to the charts of “Comparative Fluctuations of the Barometer,” he

will find a very striking example of a sudden rise of the barometer on the morning of the 21st of September, 1845, at Fort Brooke, in Florida, at the very time there was a most violent hurricane approaching, and was then within four or five degrees of that place. The barometer rose there that morning 15-100ths of an inch, though it had been nearly stationary for more than a month before. A great storm of rain reached there that day; and then in the afternoon the barometer fell 30-100ths of an inch. The barometer rose slightly at Fort Marion, one degree further off from the influence of the hurricane; and further still no rise was noted by any of my observers. These same barometric charts are full of evidence that whenever a great storm is approaching from the west it is preceded by a rising barometer; so that I consider this fact fully established; and, *without such a rise, no storm of dangerous violence need be feared*. The converse of this, however, is not always true, because a great rise of the barometer may be produced by a storm which passes by on one side of the observer. In such case the rise is not so rapid, and generally continues above the mean several days at the same locality.

172. There is a table at No. 118 which may be used as a form for a journal of the weather, with the addition of a column for "lower clouds," by all those who, on reading these remarks, shall determine to send their observations to "the Navy Department."

173. I wish all who may determine to aid the advancement of meteorology by their observations to notice the numerous queries propounded in various parts of the preceding "reports," and I will here add a few more.

How far does the cloud which passes the top of the Andes, from the east towards the west, in the neighborhood of Lima, &c., reach before it is dissolved? and what appearance does it exhibit to an observer on the coast?

During the southwest monsoon, when it is raining constantly on the Western Ghauts of Hindostan, can the clouds over those Ghauts be seen in the Bay of Bengal? and what appearance do they exhibit?

What are the phenomena attending the northers in the Gulf of Mexico, near Vera Cruz, as to the thermometer, the barometer, the dew-point, the appearance of the sky, &c.? Are clouds visible, indicating great rains, over the isthmus of Tehuantepec, at the commencement or during the continuance of the northers?

What is the appearance, in the gulf of Tehuantepec, of the clouds over the isthmus north of Tehuantepec, at the time of great rains there in the winter, while it is clear at Tehuantepec?

How far do the clouds reach south of the region of rain, and what is the temperature and pressure of the air at the time?

Where are the heaviest dews deposited on the deck, and where are there no dews? Are there any dews in the belt of high barometer in the outer border of the trade winds?

What is the greatest difference between the temperature of the air and the dew-point, especially at the beginning and end of rains, and during their continuance, and more especially at the time of waterspouts?

It is believed that waterspouts never occur only when the dew-point is within a few degrees of the temperature of the air. Has a waterspout ever been seen in the belt of high barometer within two or three degrees of latitude 31° ?

If any whirl is observed in a waterspout, in what direction does it whirl—from north by east, or from north by west? and what are all the phenomena attending waterspouts?

Is there ever a sudden squall of wind without an attending cloud, either in existence at the time of the squall, or formed overhead suddenly after?

North of the borders of the belt of constant rains, near the equator, what is the appearance of the cloud to the south? How far does the cloud extend north of the rain? Is it similar in appearance to the cloud crossing the Andes, as seen from the coast on the west?

When the observer approaches near enough to either of these clouds to have the outer edge in the zenith, does the cloud then appear to be of the true cirrus character?

In the case of the Andes, does any part of the cloud appear below the top of the mountain? and is its appearance different in different seasons of the year, and at different times of the day?

Let the same questions be answered as to the cloud seen on the north, from the Gulf of Tehuantepec.

Does the extreme edge of these clouds appear to be nearly stationary? and yet do the several parts appear to be in motion from the region of the rain, according to the description in No. 170?

Are clouds seen to form over islands, frequently, when there are no clouds over the surrounding ocean? and if they do so form and become very large and lofty, do their upper parts seem to spread outwards, finally making the cloud appear something in the shape of a mushroom?

And do these clouds, when they produce rain over the island, rapidly disappear without being carried off over the ocean? During the rapid formation of one of these lofty and large clouds, does the wind blow from the ocean towards the interior of the island on all sides, while the upper rim of the cloud is moving in the opposite direction?

I remain, very respectfully, yours,

JAMES P. ESPY.

Hon. WM. A. GRAHAM,

Secretary of the Navy.

JANUARY 24, 1851.

THEORY OF WINDS.

174. If the earth were surrounded with an atmosphere void of vapor and of the same temperature, zero of Fahrenheit for instance, the barometer would indicate the same pressure from equator to poles, and there would be no winds.

Suppose now heat to be communicated to this atmosphere, so as to make its temperature all over the earth equal to what it is at a mean when the sun is on the equator, that is 80° near the equator and zero near the poles, the first effect on the barometer would be to make it rise, especially in the torrid zone, from the expansion of the air, and its reaction downwards, and this rise would be in proportion to the suddenness with which the heat was communicated.*

In a very short time, however, the air in the equatorial regions would swell up and become eighty four hundred and forty-eighths of the whole deeper from the surface of the atmosphere down to the surface of the earth than it would be at the poles, provided no allow-

* If the heat should be communicated instantly, the inertia of the air would operate to resist expansion in such manner that the barometer would rise at the equator the first instant $\frac{1}{448}$ of the whole.

ance be made for the overflow both ways towards the poles; and then the barometer would stand again at the same height it was before.

This state of things would not continue, for the air at the upper parts of the atmosphere near the equator, and over the whole torrid zone, would flow down the two inclined planes towards the poles, causing the barometer to fall over the whole torrid zone, and rise over the whole frigid zones, and some place in the temperate zones the barometer would remain unchanged.

The barometer now standing above the mean in high latitudes, and below the mean in low latitudes, the wind would blow, in both temperate zones, towards the torrid; and from a well known cause, the rotation of the earth, these winds would be northeast in the northern hemisphere, and southeast in the southern hemisphere, and the currents above would move in an opposite direction over the temperate zones.

These currents would be very feeble, for three reasons: First, the head of pressure would be very small, when compared with the great length of the inclined plane; second, the resistance which the lower current would experience from the irregularities of the earth's surface; and, third, the constant every day upward moving columns of air from the heated surface of the earth, going into the current above moving toward the northeast, whilst the air in the current from below has a motion towards the southwest, and, therefore, by its inertia diminishes the velocity of the air above, and for a similar reason the air which comes down (for as much must come down as goes up) diminishes the velocity of the current from the northeast below. Thus each mass of air passing from the upper to the lower current, or from the lower to the upper, not only has its motion stopped, but is obliged to move in an opposite direction, and thus both currents are greatly retarded in their motion. The latter two causes would operate more powerfully on the land than on the ocean, and, therefore, the currents both above and below would be stronger at sea.

These currents would be very feeble both in the torrid and frigid zones, because the temperature at the equator is very little greater than at the tropics, and very little less at the poles than at the polar circles; whereas there is a great difference of temperature between 30° and 60° of latitude, and of course the perpendicular depth of the atmosphere is much greater at latitude 30° than at latitude 60° , $\frac{1}{448}$ of the whole for each degree of Fahrenheit of greater temperature, provided the mean temperature be considered zero at latitude 60° .

The barometer would have scarcely any or no fluctuations, but the four diurnal ones which would then be regular, diminishing in amount from the equator to the poles.—(See No. 11, note.)

There would be no belts of high barometer near latitude 30° north and south, nor belts of low barometer at sea about the arctic and antarctic circles, as we shall see there are, in an atmosphere charged with aqueous vapor.

In mountainous countries, in low latitudes, there would be gentle winds descending the slopes during the night, caused by the cold of radiation, and land and sea breezes would be more regular than they are at present, not being interrupted by rains, but there would be no violent squalls coming down from the sides of the mountains, such as are now produced by great and sudden falls of rain on their slopes.

If there were any regions of abnormal heat beyond the boundaries of the torrid zone, as the

great desert of Sahara, for instance, the wind would not blow entirely across it, as it does now to the region of rain, but it would blow towards the centre of greatest heat on both sides, below, and swelling upwards, it would blow outwards above, leaving the barometer lower than the mean below, at the central regions of greatest heat.

It is probable that the superior quantity of caloric which the upper current would have on leaving the equatorial regions would constantly be radiated off into space as it reached higher latitudes, so as to be always of nearly the same temperature as the normal of the latitude which it reached. It has been shown before that this is certainly the case in an atmosphere mingled with aqueous vapor. It has also been shown that if dry air goes up till it expands into double space from diminished pressure, it will fall in temperature 76° , if its temperature was 76° at the surface of the earth, and the barometer 30 inches.* And if it goes up to where it would expand into four times the space, it would fall in temperature about 110° , &c. We shall see presently that the rate of cooling is very different in an atmosphere mingled with aqueous vapor, when air ascends from the surface of the earth into the upper regions.

175. Before I begin to show what the phenomena are in an atmosphere mingled with vapor, it is necessary to premise a few well known principles which have been established by observation or experiment.

First. A clear atmosphere in its normal state is about one degree of Fahrenheit colder for every hundred yards of elevation above the surface of the earth over a wide extended plain for the height of many hundred yards.†

Second. The quantity of latent caloric evolved by condensing a pound of steam in one hundred pounds of water, at the temperature of 32° , would heat that water about 48° .

Third. As the specific caloric of air is about one-fourth that of water, a pound of steam, condensed in one hundred pounds of air, would heat that air about 48° .

Fourth. If vapor, at the common temperature of the atmosphere 52° , unmingled with air, should be expanded into double the space by diminished pressure, its temperature would fall 20° without any of the vapor being condensed into water; and vapor at the temperature or dew-point of 73° , being expanded into double the space by diminished pressure, would fall in temperature 21° , and be then at the dew-point of 52° ; therefore, if the vapor should now be cooled down to 32° in the same space, one-half the vapor would be condensed, and its temperature would be 32° .—(See table of dew-points, No. 164.)

176. Let us now suppose that in the hottest belt near the equator the air goes up, not dry,

* See No. 141.

† John Welsh, esq., under the direction of the Kew Observatory Committee of the British Association, made four most successful balloon ascensions in 1852. The results were read by Colonel Sabine to the Royal Society May 26, 1853. In all these ascents the temperature of the air sunk a little more than one degree for each hundred yards of ascent, until at a certain elevation, varying on different days, the decrease was arrested, and for a space of 2,000 to 3,000 feet the temperature remained nearly constant, or even increased by a small amount; then the regular diminution was resumed and generally maintained at a rate slightly less rapid than in the lower part of the atmosphere. In one of these ascensions, 21st of October, Mr. Welsh entered a cloud at the height of nine hundred yards, and the temperature remained nearly constant for about three hundred yards higher, when he passed above the cloud, and on emerging from it the temperature seemed rather to increase for a short distance.

The dew-point continued always below the temperature of the air, except when in the cloud; but it was very irregular in its variations. In the ascent of August 26, at the distance of 12,300 feet, the dew-point was 5° , while the temperature of the air was 33° —that is, 28° below the temperature of the air. In the last ascent, November 10, at the height of 20,650 feet the temperature was 10° and dew-point 22° minus.

but with a dew-point of 73° , the air itself being at the temperature of 76° , it follows, from the principles just laid down, that the air in going up with its vapor in it, and cooling nearly four times as fast by expansion as the vapor, it will soon be as cold as the dew-point, and then by a further ascent the greater cold of the air will begin to condense the vapor into water, thus forming cloud; the vapor, in condensing, will evolve its latent caloric into the air in contact with the condensing vapor, and consequently diminish the rate of cooling in the further ascent of the air in such manner that, when the air has gone high enough to condense by its cold of expansion from diminished pressure, one-hundredth of its weight of vapor, the air thus receiving the latent caloric will be 48° warmer than it would be in ascending to the same height if it had been dry air. And, as air expands $\frac{1}{448}$ th of its bulk at zero for each degree of Fahrenheit, its specific gravity will then be $\frac{48}{448}$ less than it would be if it had been dry air at the mean temperature of zero.

This will cause a much greater swelling up of the air over the region of the cloud than in the case of dry air, and a much more rapid flow of air outward, above both ways, towards the tropics, and of course a much greater fall of the barometer under the cloud, where the evolution of the latent caloric takes place.

In the case above supposed, the air, on leaving the surface of the sea, was assumed to have a dew-point of 73° , and therefore to contain about $\frac{1}{80}$ of its weight of vapor. It will be shown hereafter that the cold of expansion of air going up even to the top of the atmosphere is not sufficient, under the most favorable circumstances, to condense more than $\frac{1}{80}$ of its weight, and that it ceases to condense after the air has gone so high as to expand into six times the bulk it has at the surface of the earth, because the vapor above that point cools as fast by expansion as the air, and whatever remains in the air uncondensed at that height goes up with the air transparent to the top of the atmosphere, and rolls off with it above, being then 60° hotter than it would have been if it had had no vapor in it to condense.—(See Nos. 65 and 66.) All the air, however, which goes up in the belt of cloud will not go to the top of the atmosphere, but only that which is in the middle of the belt; that near the sides will spread outward soon after it reaches that level in which the barometer would stand at the same height as one at the same level on the outside of the ascending current. This would probably be about the level where the barometer would indicate a pressure of fifteen inches; and at all heights above that, the barometer would stand higher in the cloud than it would at the same level on the outside of the cloud. And as the air, as well as other fluids, always moves from the side where there is greater pressure on the same level towards the side where there is less, the currents above this level of equal pressure will be outward from the centre of the cloud, and inward below, corresponding thus far exactly with the motion of the dry air, only the velocity will be much greater.

The upper current, on commencing its motion towards the tropics, would be at least 40° above the normal temperature, or what it would be if it had had no vapor in it; but it would not remain so, for it would radiate rapidly its superabundant caloric into space.

How far it would go before it cooled down to a normal temperature, we would, in the present state of science, have no means of knowing, without the aid of the barometer. This we know, however, that air, with a low dew-point, has a greater specific gravity than air, at the same temperature, with a high dew-point; and, therefore, when it cooled down to a normal temper-

ature, it would sink down and make a band of descending air parallel with the belt of rain, bringing down its low dew-point with it, and, by its superior weight, causing the barometer to rise above the mean. Such a belt we find from twenty to thirty degrees from the equatorial belt of rains, and hence we may infer that the abnormal heat is radiated off by the time it reaches that distance.

We have seen before that a belt or annulus of high barometer surrounds all great storms that take place in the United States. We shall also see that the dew-point in these belts of high barometer, near latitude 30° , is much lower than it is on either side.—(See Nos. 114 to 117; also, No. 8.)

177. We are now enabled to calculate very approximately the relative depths of the atmosphere at the equator and at latitude 30° . If the whole of the vapor which the air contains when the dew-point is 73° —that is, when the elasticity of the vapor is 0.80 inch—should be condensed, it would hinder the air from cooling by expansion, from diminishing pressure as it ascended, to the amount of 80° Fahrenheit. Now, we may safely allow, as will be shown hereafter, that at least $\frac{5}{8}$ of it is condensed, which will cause the air at the top of the cloud and from that to the top of the atmosphere to be fifty degrees above the normal temperature, which would be sufficient to render the mean of the whole column about 38° above the normal. If to this we add 10° for the difference of latitude from the equator to latitude 30° , the equatorial belt, from the surface of the earth to the surface of the atmosphere, will be 48° warmer than the belt at 30° latitude; and its specific gravity in the colder belt, if the mean temperature of the warmer is zero, would be one-tenth greater than in the warmer belt; therefore, if the barometer stood at equal heights at these two localities, the depth of the atmosphere at latitude 30° would be one-tenth less than at the equator, with a small increase of difference on account of the greater dryness of the air at latitude 30° than on either side, north or south. The effect produced by this latter cause would be very minute, if it depended merely on the difference of the quantity of vapor which two columns of air at rest would contain—one at the equator, and one at latitude 30° ; but when it is considered that the column at the equator is, by its upward motion, constantly carrying up from the surface of the sea new vapor, sufficient to keep the whole column saturated with vapor from the base of the cloud to the top, where the barometer stands only about six inches high, though a large portion of that column is 20° to 40° warmer than the other, it of course could contain, even if the colder column was saturated, from two to four times as much vapor at these respective temperatures. It appears, at first, a little paradoxical, that a column of air, in which a large quantity of vapor is constantly being condensed, should still have in it twice as much vapor uncondensed as another in its neighborhood with the same dew-point at its base; but such is the fact. For in the normal state of the air, where the temperature, for instance, at the surface of the sea, is 76° , it is zero at a height where the density of the air is only one-half, and a given space there could not contain one-eleventh of the quantity which the same space could contain at the surface of the sea below. In the extreme case of a dew-point of 80° , the proportion of weight of vapor in a cubic foot of air is only $\frac{1}{48}$; and if each cubic foot of air from the surface of the sea to the surface of the atmosphere contained one forty-eighth of its weight of vapor, this vapor, if all condensed into rain, would make only a depth of eight inches and one-half of water over the region of condensation. It therefore may be safely said, without going into a more minute calculation, that with

the highest dew-point that is found on the surface of the sea, the atmosphere never contains at any one time vapor enough to make three inches of rain, if it were all condensed and should fall in rain, leaving the air entirely dry.

Without entering into a minute calculation of the superabundant quantity of vapor in the up-moving current of air at the equator over the down-moving current at latitude 30° , which might be done, because the temperature of the air in both the up-moving and down-moving currents is known from the top to the bottom nearly, as also their respective dew-points, let us suppose, what is not far from the truth, that the up-moving current contains enough of vapor to make four inches of rain, and the down-moving current enough to make one inch, the superior quantity in the equatorial cloud belt will be equal to three inches. Now, four hundred inches deep of rain is equal to the weight of the whole column of atmosphere; therefore, three inches is $\frac{3}{400}$ of the whole weight; and as the specific gravity of vapor is only $\frac{5}{8}$ of that of air, it follows that the specific gravity of $\frac{3}{400}$ of the whole atmosphere is $\frac{3}{8}$ less than it would be if it had but the vapor of one inch of rain in it—that is, the barometer being the same at both stations, the air would be swelled up by the vapor in the band of rain $\frac{3}{8}$ of $\frac{3}{400}$ of the whole, or, if the atmosphere is 45 miles high, $\frac{3}{8}$ of $\frac{3}{400}$ of 45 miles, equal to one eighth of a mile; or, if the air at the top of the moist zone should run over with infinite velocity towards the dry zone, so as to keep the surface of the two zones on the same level, then the barometer would stand 0.084 inch lower at the base of the moist zone than at the base of the dry, from the difference of the quantity of vapor contained in them; therefore, from the combined effect of heat and moisture, the difference of the barometer at the two bases would be 3.0860 inches, provided the depth of the two zones was the same. This state of things could not exist long, even if it were supposed to exist for a moment; for the superior weight of the column, or rather belt of air, at latitude 30° , would squeeze the air out at the base on both sides towards the north and south, and the air above could not at first run in both ways as fast as it would run out below, until the top of the column had sunk to a considerable depth below the level on each side; and whenever that point was reached the barometer below would cease to fall, and by examining how much the barometer had actually fallen, the depth of the atmosphere at latitude 30° can be ascertained, or, in other words, the depth of the hollow. It is certain, from theory, that the hollow cannot be so great as to cause the barometer under it to stand as low as the one at the equator; for if it did the air at the base would not be pushed out at all, though the air at the top would run in with great rapidity, and these two things are inconsistent one with the other.

To know the actual depth of the hollow, or how much shallower the atmospheric ocean is at latitude 30° than it is in the rainy belt at the equator, we have only to find out by observation how much the barometer at 30° latitude stands above the one at the equatorial belt of rains, and subtract the difference from 3.086 inches, as ascertained above. Let us assume that 0.30 is this difference, and various navigators have found about that quantity, and if we subtract 0.30 from 3.086 it leaves 2.786; and as we found before that an increase of $\frac{3}{30}$ specific gravity in the air would shorten the depth of the atmosphere 4.5 miles, then we will find that $\frac{2.786}{30}$ will shorten it 4.12 miles; so that the hollow at latitude 30° north and 30° south is four miles and twelve-hundredths deep.

178. It is curious to consider what would be the velocity of a body running down an inclined plane four miles and twelve hundredths high, without friction or resistance from the air. The

uppermost stratum of air from the equator to latitude 30° is nearly in this situation ; it certainly would not meet with resistance by passing through the air, because it does not pass through it, and it experiences extremely little resistance from the inclined plane on which it moves, because the plane—that is, the stratum, just below, moves almost as fast as it in the same direction. Now, a body moving down an inclined plane 4.12 miles high, without resistance of any kind, would acquire a velocity of 1,180 feet per second, or 804 miles per hour. This is only forty times faster than the motion of the lowest stratum of the same thickness, say of 100 feet, though this last is far more than forty times as dense.

It would appear, then, from this calculation, (though the velocity of the uppermost stratum of 100 feet thick is greater than any one would have thought,) that all the air which goes in below could not go out above ; but this difficulty will be removed by considering that all the strata that are below the uppermost one, down as low as where the barometer in the inside of the cloud stands, at the same height as one on the outside at latitude 30° , on the same level, (and that will probably be between three and four miles high,) are *pushed* out by a greater pressure above them, from the greater height of the atmosphere above the cloud.

From this investigation it appears how foreign from the truth is the opinion of those who think that the fluctuations of the barometer depend to a great degree on the different quantities of vapor contained in the air at different times. In the extreme case calculated above the standing of the barometer under the column, with four times as much vapor in it as the other, was only 0.086 inch lower ; and it will be shown hereafter that in very favorable cases, with a high dew-point and cold air above, and narrow up-moving column, permitting the expanding air in the cloud to roll off rapidly, the barometer will fall three inches, by the effect of the latent caloric from vapor condensed in the formation of the cloud.

Thus far I have shown that the barometer ought to stand higher at latitude 30° than at the equator, especially in those regions where there is a belt of rain at the equator. But should it stand higher at latitude 30° than at latitude 60° or 65° ? It certainly would not if the atmosphere had no vapor in it. In point of fact it does stand higher. Let us examine the operation of vapor in producing this effect. First, as the air in the down-moving current at latitude 30° contains much less vapor in it than air just on either side of it, its specific gravity will be greater, and the air will roll in over it from both sides above and run out from both sides below, not so strong, however, on the side next the poles, unless there is a cause of aspiration in that direction as great as there is towards the equator. If we were left merely to theory, without knowing the facts, we would probably suppose that the *vis a tergo* at latitude 30° would drive the air below to the frigid zones, and there make it rise all over these zones, carrying up all the vapor it might have in it, and condensing it into unceasing rains and snows, and swelling up the air by the evolution of latent caloric, and spreading it out above to go back again to descend at latitude 30° . But when we know the facts, we are able to discover a much more satisfactory mode of getting the air which blows out below towards the poles from latitude 30° back again above. It certainly cannot be doubted that all the air which blows out below does return above ; for there is no region between 30° and 60° in which the prevailing winds are not towards the poles ; and if it did not run in above there would be no air to keep up the supply for the out-blowing of the winds below.

179. The fact is that the frigid zones are very much colder than the temperate, and therefore

the air above standing higher in the temperate rolls over constantly into the frigid zones, leaving the barometer just on the outside of these zones below the mean, and raising it above the mean in the frigid zones. The air must rise, then, when the barometer falls; and when the air rises it takes up its vapor with it, and if the dew-point is even 32° it contains enough of vapor to heat up the air, in which it is all condensed 20° ; and this will cause the air in the region of the up-moving column to stand $\frac{20}{448}$ higher than if it had no vapor in it to condense, the mean temperature being zero; and so it will cause the barometer to fall when it rises up and flows over towards the pole, and it will cause the barometer to rise above the mean all round the pole and at the pole.

The polar column of air then will sink down by its greater weight, causing the air at its base to flow outwards in all directions, thinning off as it spreads outwards in the form of a wedge, while the air from the temperate zone will flow up the inclined plane of colder air thus pushed out by greater pressure from the polar regions. Now, on the ocean at all seasons of the year, the air below, which comes from lower latitudes, will be nearly saturated with vapor, and of course where it rises it will make a belt of rain and low barometer, which in these high latitudes will have a much greater effect in drawing by aspiration the wind from the temperate towards the frigid zones than the greater pressure at latitude 30° will have in causing the winds to blow in that direction by propulsion.

It is true there is not so much vapor to condense in these bands of polar circle rains, yet the effect may be greater on the barometer than it is at the equatorial band, provided the air which swells up over the region of rain can spread out with greater readiness, which it will do if the band is not so broad; and besides, there is one ninth greater effect produced when the vapor congeals and falls in the form of snow; for then the 140° of caloric of fluidity is given out into the air, as well as the 1200° of caloric of elasticity. The fall of the barometer under a forming cloud depends more on the readiness with which the air can spread itself out and remove the superincumbent weight from the barometer below than upon the quantity of vapor in the air.

If we suppose the air near the polar circles over the sea to be ten degrees warmer than the air over the frigid zones, and besides be increased 20° at the top of the cloud by condensing all its vapor at the dew-point of 32° or rather $22^{\circ}.3$ if the vapor when condensed is frozen, then will the whole column containing the cloud be at least 20° warmer than the column over the interior of the frigid zone free from cloud, if the upper air has had time to radiate off its abnormal caloric, and its temperature below enables us in some degree to judge whether this is so.

Now, if we suppose the temperature of the warmer column to be at a mean zero, and 20° warmer than the other, then is it expanded $\frac{20}{448}$ of the whole, and if the air should flow off above as fast as it rose, so as to keep the upper surface of the atmosphere of both columns on the same horizontal level, then would the barometer below in the middle of the up-moving current be $\frac{20}{448}$ lower than it would be if the two columns were of the same temperature. Now $\frac{20}{448}$ of 30 inches of mercury is $1\frac{1}{2}$ inches. But as the air of swelling up over the belt of rain would actually flow off with considerable rapidity towards the poles, the barometer would rise at the poles and fall at the polar circle belt of rain, a quantity which can only be determined by actual observation.

It has been shown 94 to 98 that in the southern hemisphere the barometer is at a mean nearly

an inch below 30 inches, in a belt all round the world, between 60° and 65° and that in receding from that belt either north or south the barometer rises. It has been shown also, that the wind on both sides blows directly or obliquely towards that belt almost constantly, and that it almost constantly rains or snows there.

Now, if any one of these facts, and only one, should be known, it follows from the theory here propounded that all the others could be certainly inferred. For instance, if navigators by numerous observations have shown without doubt that there is a belt of almost constant rains or snows, then the air must ascend in that belt to condense the vapor, and of course the wind must blow on both sides of that belt, directly or obliquely towards it, and if the wind blows towards it, the barometer must stand lower in the belt than at either side.

The great continents of Asia and Europe and North America interrupt and nearly obliterate these belts in the northern hemisphere, but still there is a belt of rains, well defined, in about latitude 60° both in the Atlantic and the Pacific, with the other phenomena of a low barometer, and convergence of the winds. On land the rains are diffused over the whole region from the polar circle, and even beyond down to the belt of high barometer in latitude 30° .

180. In the belt of high barometer where the air is sinking down and bringing with it an extremely low dew-point it can hardly ever rain on lofty situations, such as the Andes of South America. Hence the mountain Acongagua near latitude 30° south is sometimes free from snow, though it is 1478 feet higher than Chimborazo. At sea, however, the air coming down into contact with water will not be long in acquiring, (by its motion and mingling with the spray of the waves,) a dew-point not far below the temperature of the water with which it is in contact, and by the mingling of the air this dew-point may extend many yards high before it gets out of the belt of high barometer. And if an up-moving column of air should be formed out of this moist air, it would go on increasing in rapidity as it ascended, notwithstanding the dry air all round it was coming down. Such a kind of air, with a high dew-point in the lower stratum, fifty or one hundred feet thick, would be particularly well suited to produce tornadoes.

In a tornado the lowermost stratum of one foot of air touching the earth or sea goes up in the middle, the second foot above goes up next to the middle, and so on in succession; and in fact it is only the lower stratum of perhaps less than fifty feet high that goes up at all, for that amount of air, running in on all sides for three or four hundred yards, is sufficient to furnish the whole ascending column.

Nor is the dry air in the belt of high barometer unsuitable to the passage of a great hurricane through it, as will appear from the following considerations. When a great West India hurricane comes within disturbing influence, which it does several hours before its greatest violence, the wind raises the waves and lashes them into spray, rapidly increasing the quantity of vapor in the air, and mingling several hundred feet of the lower air together, whilst, at the same time, the wind will prevent any regular up-moving currents to be formed so as to produce local clouds and storms, and thus when the centre of the hurricane comes into the belt of dry air it will find a stratum of nearly saturated air, of sufficient thickness to furnish the necessary quantity of vapor at least to the central parts of the hurricane; and if the size should be diminished in consequence of the thinness of the stratum of air filled with the vapor, its action would become more violent on that account, for, the smaller the up-moving column the more easily will the air in the upper part spread out and relieve the lower part from its pressure; and

besides, the air around being dry, except near the surface of the sea, would be heavier than the moist air at latitude 10° or 15° from which it comes, would form a greater contrast with the middle of the hurricane with its high dew-point. Indeed, it appears probable, from this view of the subject, that if a hurricane should come into the belt of high barometer and find there only a very thin stratum of air with a high dew-point, it would still continue, but might dwindle down in volume even to that of a water spout.

181. As hurricanes, however, do, in fact, cross this belt of high barometer, we may safely infer that they find a stratum of air at the surface of the sea, charged with vapor, of sufficient thickness to continue the hurricanes and produce the great rain which always accompanies them.

It seems, however, highly probable—almost certain—that the stratum of moist air in this belt cannot in any case be as thick as the stratum of moist air on each side, and the effect of this must be to diminish the diameter of the hurricane in its east and west diameter more than in its north and south, so that if it was round on entering this belt it would become oblong while in it, and probably continue so after it left it; in which case the wind below would blow inwards on the east and west sides towards the longest diameter with greater violence than it would on the north and south; because the air above could roll out east and west with greater rapidity than in could north and south.

It is certain that nearly all of our great winter storms are five or six times as long north and south as they are broad from east to west, as they pass side foremost towards the east over the United States and enter the ocean in that shape, where the ships on our coast receive their violence first from the eastward and then from the westward, just as the observers do in the whole of the United States from the extreme north down to near latitude 30° . How far these storms extend north is not yet known; it is probable that they extend to near latitude 60° , for the barometer sinks, on their passage, lower on the north of the United States than further south, and the wind generally changes round to west by south, unless it sinks to a calm, on the passage of the line of least pressure, as shown by the barometer. It is certain that if the point of least pressure in a storm, as it moves from west to east, passes to the north of an observer, the wind to him will change round from east by south, and if the point of least pressure passes to the south of him, the wind will change round from east by north. This will be the case whether the wind blows inwards towards a central line or round a central point in a circle. The shape of these long, narrow winter storms, however, utterly repudiates the notion of a whirlwind in them; whether there is or is not a whirl in the hurricanes and tornadoes, and the fact, now demonstrated, that the wind does actually blow in from the borders of the storm towards a central region, refutes the notion of Sir John Herschel, that if the wind were to blow in towards the centre of a storm the barometer would necessarily rise the above there mean.

182. It, no doubt, has occurred to the reader before this that I have not fully explained how all the air which blows out towards the poles from the belts of high barometer in latitude 30° , gets back again above to supply the place of that which is continually flowing out below. The first observation I have to make on the subject is, that it certainly does get back above, whether its mode of getting back can be explained or not. Next, it is manifest that it does not all flow back from the belts of rain near the polar circles, for as the belts of high barometer are nearly twice as long as the belts of rain near the polar circles, the air which blows out from the belts of high barometer could not all reach the polar circles without either making the barometer rise

greatly above the mean, or else increasing in velocity both below and above nearly double; neither of which takes place.

Let us reason from known facts. The barometer actually stands higher at about latitude 30° than it does at latitude 40° or 50° ; the air will therefore be pressed out at the lower part of the atmosphere from 30° towards 40° and 50° ; and as the barometer stands still lower at 60° than 50° the air will be pressed onwards towards 60° . It will there, or near there, meet a wind coming from the poles, being pressed in that direction by a high barometer in the polar regions, and these two currents would soon bring themselves to equilibrium, if the air had no vapor in it; but as it has vapor, the effect will be as was stated before, the current which meets the polar current at least has vapor, and in rising will expand, by the evolution of the latent caloric, and swell up much above the air at the top of the atmosphere on both sides and roll out both ways exactly as much as runs in below. Now, though the quantity which runs out above from the polar belt of rains and low barometer is exactly as much as runs in below, it is not more than half as much as runs out below from the tropical belt of high barometer and dry air, and it remains to account for the difference, for, certainly, exactly as much runs in above at the tropical belt as runs out below.

The following considerations I think will explain not only how the air all gets back and runs into the hollow above at the belt of high barometer, but why the wind blows between this belt and the polar belt nearly from the west; south of west in the northern hemisphere and north of west in the southern.

In consequence of the great distance between the polar and tropical belts, and the slowness with which both the upper and lower currents move, the presumption is that the upper current which starts from the polar belt towards the tropical will not go far till it has radiated off all its abnormal heat, which it received from the condensing vapor as it rose in the belt of rain; and of course when the air became heated below by the sun shining on the earth, up-moving columns would be formed, carrying up with them the vapor which they might contain, and, by the cold of expansion, this vapor would condense, which would give out its latent caloric, and thus cause the air to ascend to the top of the atmosphere, and spread out in all directions above, producing a fall of the barometer below in proportion to the suddenness and quantity of vapor condensed and the ease with which the air could roll out above. This would take place generally in showers and storms over the whole region between the tropical and polar belts, so as completely to mingle the upper and lower currents together, for all round every up-moving current there comes downwards as much air as goes up—thus the upper and lower currents would have to take some intermediate direction between the two. And as much more air came out from the base of the tropical belt than is returned from the upper part of the polar, and as the air which came out of the tropical belt started towards the northeast in the northern hemisphere—that is, it was a southwest wind, and in the southern hemisphere was a northwest wind—in consequence of the revolution of the earth on her axis, these winds would not blow long on the surface of the sea till they would become moist and warm; that is, contain more caloric to the pound than the upper current, which would be at a normal or nearly a normal temperature, and, therefore, up-moving currents would be formed, producing rain as before explained; and thus an intermingling of the air above and the air below would take place to some degree, and therefore they would take, in some degree, the same direction; and as the

lower current is constantly renewed by air coming down and blowing outwards at the belt of high barometer, the direction would continue to have westing in it. This will be seen more clearly when we consider the direction of the current both above and below at the polar circles.

Let us examine the north polar belt first. The wind reaches that belt at the surface of the earth blowing from the southwest, it then rises without mingling with the air which comes from the northward, and meeting with no friction in its ascent, its northern motion is changed to a southern, but its motion towards the east is continued, and it rolls over from the arctic circle towards the southeast; and, therefore, when up-moving currents are formed at some distance south, the currents both above and below will become more easterly, still remaining, however, southwesterly below and from north of west above, in consequence of the continued forces in this direction at both ends of the currents. It is acknowledged that though the upper current is pushed outwards from the arctic belt of rains without diminishing its motion towards the east, it would not go far to the south before its direction would be from the north and finally from the northeast in consequence of the rotation of the earth; but probably before it would reach that distance it would meet with up-moving columns of air from the lower stratum, coming from the southwest which would make its direction more easterly, that is, towards the east, and the air which would come down from the upper current to the lower would also cause the lower current to move more towards the east; and as this would take place all over the temperate zone north of the tropical belt of high barometer and downward motion of air, (for it actually rains over all this region,) the direction of the lower current over all this region would be from a little south of west and the direction of the upper current would be from the north of west, though pretty nearly from the west. This last deduction of theory is the only one in this discussion which has not yet been fully established by observation, and its establishment or refutation will be decisive as to the correctness or incorrectness of this part of my theory, and yet all the observations made on this subject are favorable.—(See 215.) I may add, however, that if it shall be established that the wind blows from the belts of high barometer all round the globe, both towards the equator and towards the polar circle, then it will follow that equal quantities flow in at the upper parts towards the belt of high barometer, and this it would not do unless there was a hollow there, and there would not be a hollow there unless the specific gravity of the air in that belt was greater than on either side, either from greater dryness or greater cold, or both.

One thing is certain, that the prevailing course of the wind in the torrid zone is from the east, and from that fact it may be safely inferred that the prevailing wind in the temperate zones must be from the west; for if it was not, the friction of the wind in the torrid zone would constantly diminish the velocity of the earth's rotation, unless the force causing that wind were from within the earth, and then it would constantly increase the velocity of rotation on the earth's axis, and as neither of these results takes place, we may infer that there is just as much friction by western winds as there is by eastern.

183. It need hardly be mentioned (because it is so manifest) that these belts would all move north and south with the sun in his annual progress to the north and south, though not near so far, as the sun moves; for, if they did, the belts in the summer of each hemisphere would be crowded too close together; and they have such a dependence on each other as to render such proximity impossible. If the earth were very much larger than it is, with the same atmosphere,

it is probable that there would then be four more belts formed, two on each side of the equator, one of high and one of low barometer. There could not be less than two on each, for the belts of high and low barometer must alternate, counting from the belt of low barometer at the equator and terminating with the belt of high barometer at the poles.

Is this the plan on which the atmosphere of the great planet Jupiter is constructed?

If the earth were covered with water, there would be much more regularity in these belts than there is at present, both on account of humidity of surface and freedom from prominent elevations. The belts then would move backwards and forwards with the sun, perhaps from ten to twenty degrees annually, and thus produce a change of winds called monsoons to that amount of latitude. These monsoons would be produced as well by the motion of the belts of high barometer as by the motion of the low.

Suppose, for the sake of illustration, we take the belt of high barometer at latitude 30° north. In our summer, this belt would be some degrees further north—say at latitude 40° ; and in the winter this belt would be some further south—say at latitude 20° ; then, in the winter, the wind between latitudes 20° and 40° would blow from the southwest, and in the summer from the northeast. In our summer, too, the belt of rains would be north of the equator, and in the summer of the southern hemisphere the belt of rains would be south of the equator; the polar belts also would approach nearer to the poles in summer of each hemisphere, and on each side of all these mean belts there would be monsoons to the extent of the motion of the belts.

184. If now we suppose the ocean to be interspersed with land and high mountains, much greater irregularity would be caused, both in the regular winds and with the monsoons. For example, if there should be elevated very high mountains entirely across the torrid zone and beyond, such as the Andes, the wind established from the east would swell up on the east side by the latent caloric given out in its upward motion, and pour down all its rain on the eastern side of the mountain, sending only the upper part of the cloud over the top containing too little condensed vapor to produce rain much beyond the summit. The particles of the cloud would sink down in the air below, and, by evaporating there, cool the air, and keep it constantly cooler by many degrees than the mean temperature of the climate, producing also overhead a haziness almost concealing the sun, which would extend in thinning out several hundred miles from the top of the mountain over which the cloud was thrust, as is the case at Lima.

As all the air of the trade-winds is obliged to pass over the top of these lofty mountains, where the air is hardly at half the density as it is at the surface of the sea, the velocity of its motion on the top of the mountain will be proportionally greater than it is on the plain below. Although the particles of cloud, on going over the mountain to the west, sink and evaporate in the air below, the air itself, on passing over, having in it yet nearly all the latent caloric given out on the east side of the mountain, will swim off and go some hundred miles before it radiates off all its abnormal caloric. In the interval, the trade-winds will be intermitted, and if there is any cause to produce a cross motion of the air near the coast it will be free to act. The air, however, which comes over the mountain will gradually part with its heat, and when it becomes of a normal temperature, it will slope downwards and finally reach the ocean, and then the trade wind will appear. In this whole region there can be no rains, unless the fine mist falling about the coast, known by the name of garua, is called rain. This, as was said before, falls out of the thin cloud that passes over the mountain from the east; and the same phenomenon would

always be seen just beyond the equatorial belt of rains, both on the north and south sides, if it was not that the wind there blows it constantly in under the rain cloud as fast as it descends from the thin cloud spread out above.

Even after the trade winds are formed again, several hundred miles west of the South American coast, they will blow regularly without rain, except in the belt between the northeast and southeast trades, unless they should meet in their way a group of islands, and then, if up-moving currents are formed, sufficient to produce great rains, the winds west of these islands will be reversed, and thus the trade winds will be interrupted; and such is said to be the case. This interruption is the more remarkable as it takes place on the south side of the equator, a thousand miles further east than it does on the north side, and that it continues regular on the north side of the equator till it there too meets with islands.

But the Andes extend south far beyond the belt of high barometer, into a region where the winds largely prevail from the northwest, and here the same phenomena take place, in a reversed order. The winds which blow on the western side of the Andes discharge their rain on the western side, and go over to the eastern side rainless, and, as there is land there, a desert of extreme aridity is the consequence; for, while it is raining almost every day on the western side of these mountains, it seldom rains a drop on the plains adjoining the eastern slope. The rain on the western side or slope will always be violent in proportion to the violence of the west wind, and, where the slope of the mountain approaches near the sea, the great weight of the descending rain, pressing on the air below it as it is falling, will reverse its motion in a thin stratum near the surface of the slope, and drive it down with great violence for some distance out to sea; and the mariners have learned, in such cases, to know that the *wind does not blow home*. It is worth while to mention here that, between these rainy regions, about latitude 30° , there is an extremely arid region, reaching even to the top of the mountains, where it seldom rains, and where it would never rain if the band of high barometer did not change its position, producing monsoons. This is the region where the air comes down and brings its low dew-point with it. It is in the belt of high barometer. This belt is further south when the sun is south of the equator, and further north when the sun is on the north of the equator; and, if it is recollected that the wind always blows out from this belt below, it will be easy to recollect in what direction the monsoons in this region blow in the different seasons of the year.

These are some of the phenomena which are produced by a high mountain placed north and south across the torrid zone and beyond.

Now let us consider the effect of a high mountain running nearly parallel with the equator and placed where the zone of high barometer would be in its normal state, just as the Himalayas are.

185. In the winter season, when all the zones, both of high and low barometer, are removed further south than their mean, the northern tropical zone of high barometer is south of the Himalayas, and the air which is pressed downwards in that zone is made to run out at its base, and, of course, the northeast trade winds will be well supplied with air, as all the air which comes down in that band will be obliged to blow out below towards the equator; for the Himalayas being then just north of this belt will prevent the wind below from blowing out in that direction. A small portion of this air in its passage will strike against the eastern Ghauts of India, and having been pretty well saturated with vapor in passing over the Bay of Bengal, it will

rise there and produce rain, and cause this to be the rainy season in a small portion of the south-east part of that country.

186. This northeast monsoon will now go to the belt of low barometer, which at this season is south of the equator, and after it crosses the equator it becomes a northwest wind, called in the Indian ocean the northwest monsoon. This monsoon is met by the southeast trade wind, and between these two winds is the belt of low barometer, and, of course, upward motion of the air, great condensation of vapor by the cold of expansion from diminished pressure, great evolution of latent caloric, in the condensation, great diminution of specific gravity in the column of air receiving this latent caloric, a great overflow above towards the belts of high barometer on each side, and a great fall of the barometer, with violent and almost constant rain and wind below. This band it is known reaches from near Madagascar in the west to the northern part of Australia, or beyond, in the east, six thousand miles long.

Now it is quite probable that in so long a band the inward motion below and the upward motion in the middle will be more violent in some places than in others, and, of course, a more rapid condensation of vapor and evolution of latent caloric, and a greater fall of the barometer; if so, there would be an inward motion on all sides towards one common centre; and as the wind on the north of this centre would be blowing from the northwest, and the wind on the south of the centre would be blowing from the southeast, it is manifest that in approaching a central point they would gyrate as the hands of a watch laid on its back. Between these columns of violent up-moving action there would be a point or space of more or less magnitude, where there would be a calm, from which the wind would blow towards the up-moving columns on each side, and therefore the air would come down over this calm region, and then so far from producing cloud over that region, the clouds pushed over it above from the adjacent up-moving columns would be dissolved by the heat of increased pressure as they descended, and thus would produce a clear space over the region of calm.

187. In the mean time there being but little air between the up-moving columns and abundance on the outside, to supply air for the upward motion, (for these two columns are supposed to be closer together than the others beyond them,) the columns would approximate and finally coalesce, and during this process an observer would see the clear space over his head, called the "eye of the storm," with that dismal, dark, lurid appearance, closing in upon him on all sides, so vividly described by various mariners.

During this state of things there would be an increase of heat from the radiation of the abnormally heated air above, there being no clouds to intercept the radiation, and if any of the air itself thus abnormally heated should reach the observer below, the heat would be very oppressive. During this calm also the sea would be violently agitated, and the barometer would be a few hundredths of an inch higher than it would be in the centres of the ascending columns on each side.

The same appearances may take place when the centre of a completely formed hurricane passes over an island. The wind may glance up round the borders of the island in such a manner as to form a ring of violent action all round the borders of the island, and the "eye of the storm" may be formed over the calm in the middle of the island, in the manner just described. Nor is it unreasonable that such a phenomenon should appear in the open sea, in a hurricane of great diameter, for the air coming in on all sides under the storm cloud, where

the barometer is much depressed, will slope upwards and condense all its vapor that it can condense by the cold of expansion from diminished pressure, before it reaches the centre; and as there will be in this case a calm of considerable magnitude in the centre of the storm below, it is manifest that there is no air going up from that region, and the small piling up of the air in the upper part of the atmosphere, caused by the inward and upward direction of the air in the parts of the storm around the central space, might make the barometer rise over the calm space four or five hundredths of an inch above that of the regions of the storm where the air was ascending with great rapidity; the air in the central part of the storm would thus gently descend, which would cause any thin cloud, which might be thrown over this space from the clouds around, to disappear very soon by the heat of increased pressure as the air over the central space descended, and thus would be formed the "eye of the storm" in the open sea.

It may be mentioned here, though in anticipation of what will be more fully noticed hereafter, that the southeast trade wind to the south of this long belt of rains which reaches entirely across the Indian ocean, 6,000 miles long, seems but little, if at all, affected by the proximity of the heated plains of Australia, for on the northwest of that great island these trade winds blow still from the southeast directly from the heated land, proving that the latent caloric evolved by the condensation of the vapor in the rain belt is much more efficient in producing winds than heated dry plains.

If there was a high mountain in Australia running east and west at latitude 30° south, the regions north of that mountain in Australia would be as rainy in the southern summer as Hindoostan in the northern summer, as will appear when I explain the cause of the abnormal extent of the southwest monsoons in that country, which I proceed to do:

When the sun returns to the northern hemisphere, all the belts of high and low barometer move with him to some extent, and as soon as the belt of high barometer is removed to the north of the high mountains of the Himalayas, the wind which blows out below from that band will be prevented by those mountains from blowing towards the south to make the trade winds. This will produce a comparative calm south of the mountains, and thus a favorable state of things for producing up-moving currents reaching high enough to produce rain, which can seldom or never occur in the regular uninterrupted trades. As soon as the first considerable rain takes place, which will probably be on some of the southern Ghauts, the air will swell up over the rain from the evolution of latent caloric, as explained before, and roll out above, and some of it will find its way over the tops of the mountains to the north, increasing the weight of the air beyond the mountains; but however great the pressure there, it will not be permitted to blow towards the region of the rain to the south, being prevented by the mountain; the barometer, therefore, must stand now below the mean, unless it is supplied by air from the south, and, therefore, there will now be no longer a calm, but an inverted gentle current from the southwest. The up-moving currents will then increase in strength, an increased quantity of latent caloric will be evolved, an increased swelling up of the air over the region, and an increased flow of air over the top of the Himalayas, and so the process will be continued, till a return of the sun to the south shall bring the belt of high barometer south of the mountains, and then the northeast trades will commence, being supplied with material by the downward motion of the air in the belt of high barometer, and the rain will cease, except on the eastern Ghauts or the southeast of Hindoostan.

188. If this is the true explanation of the abnormal extension of the southwest monsoons in this region, several remarkable phenomena may be observed.

In consequence of the loftiness of the mountains, almost all the vapor that is condensed by the up-moving current of air will deposit its rain and snow on the south side of the mountain, and therefore the snow will lie at a much lower level on the south side of the mountain than on the north.

As the air which passes over the top of the mountain will contain 30° or 40° of abnormal heat, just evolved by the condensation of the vapor on the south side, the valley just north of the first range of mountains, though it is higher than the snow line on the south side of the mountains, will be warm enough to produce grain in abundance to the farmers of that lofty region, even above the snow line on the east side of the Andes, in the torrid zone.

Where there are paroxysms of rain south of the mountains there will be paroxysms of wind from the south on the top of the mountains, for at this great height the air always blows out from the cloud, and as it is known that in regions of every day rain there is an increase in the day, the wind will be found at great heights on these mountains very violent in the early part of the afternoon, blowing from the southward, with a rising barometer, causing the air at great heights, in a rapidly forming cloud, to blow outwards by propulsion.

When the belt of high barometer is just on the Himalayas, and a portion of the descending air in that belt comes down on the south side, the air at the surface of the earth in the northern parts of the country, near the base of the mountains, will be found to have a very small quantity of vapor in it, and the dew-point will sometimes be 50° or 60° below the temperature of the air.

The air which passes down the other slope will be in the same situation, and as that is the case, more or less, at all seasons north of the mountains, there will be an arid desert there.

During the summer the great rains in Hindoostan will remove the belt of high barometer to an abnormal distance north, or northeast, and under that belt there can be but little or no rain, in consequence of the extremely little vapor in the air, on its descent from the upper regions. Erman says that two divergent winds, both of great aridity, take their origin in the elevated table land of the Mongolian steppe, one going to Irkutsk, in the north, and the other to Canton, in the south, commencing in the latter place in October. And Roberts, in his Embassy to the East, says that the northern wind at Canton lasts from October to March, and is southerly and southwesterly from April to September. Dobell and other travellers give a similar account.

In October, then, as the wind blows outwards both to the north and south from the desert, the belt of high barometer must be there, and is probably not far from latitude 40° north, in a region northeast of Hindoostan, and, of course, it is in a higher latitude during the summer; but wherever this partial belt may be, according to the theory here developed, the wind ought to blow from it towards the Himalayas, and having but little vapor in it, but little rain would be produced either on the north of the mountains, where it ascends, or at the belt of high barometer, where it descends. These winds are both so dry as to cause the floors and other wood-work to split.

The direction of the wind on the north side of the Himalayas during the rainy season on the south is a deduction from theory, but I have not been able to ascertain how it is in fact. Should it be found that the air blows from the north side of the Himalayas towards the desert of Cobi,

still the region over which it blows must be extremely arid, for then the air will have to blow down the northern slope to furnish the material to keep up the wind; and if it does thus come down from the mountain it brings its low dew-point with it, and must produce aridity wherever it blows.

In fact, it may be on the north of the Himalaya in the summer as it is on the west of the Andes all the year in the torrid zone, where the wind which blows from the east over the top of those high mountains, producing constant rains and snows on their eastern slope, floats off to the west on the air below, and does not touch the sea for several hundred miles from the base of those mountains, and produces no rain for many hundred miles more.

If this should be found to be the case north of the Himalaya, then the only rain obtained in the summer, in the region near the northern base of that mountain, will be a slight drizzle from the thin cloud carried over the top, as is the case at Lima, and other places along the coast of Peru—a cloud hardly ever dense enough to entirely conceal the sun's disk.

To settle this matter many more facts are necessary, for the abnormal extension of the southwest monsoons, in this region, breaks up both the belt of low barometer to the south of it, and the belt of high barometer to the north, in such a manner that theory alone is not able to predict all the phenomena. One thing, however, is certain from theory, and that is, that the wind does not blow in on all sides towards the desert of Cobi, and rise there and flow out above; for if it did, the whole region over which the air rose would be flooded with rain as long as the inward and upward motion of the air continued.

I am well aware that this statement is contrary to the opinion of all meteorologists that have written on the subject. And yet I am willing to put the theory to the test on this point; for if the doctrine taught in the books is true, that the wind blows inwards on all sides towards the centre of hot arid deserts, such as the great Sahara, then is the theory here advanced not true.

On this subject the distinguished meteorologist, Dove, says, (and I believe most writers on the subject agree with him,) that "the high temperature developed in the summer months over the continent of Asia determines a powerful ascending current, which considerably lessens the atmospheric pressure, and becomes a centre towards which the adjacent masses of air are drawn. Therefore it is that the southeast trade wind, converted into a southwest monsoon, follows the retreating northeast trade up to the foot of the Himalaya; therefore, at the same season, cold northwest winds, which often render our summers so uncongenial, pass over Europe; east winds prevail on the eastern coast of northern Asia, (Udskoi,) and northern winds on the coasts of the Siberian polar sea. The mass of air ascending over Asia in the summer flows away laterally in the higher regions of the atmosphere, and is accumulated at the temporarily convex summits of the isothermals, as appears from the annual curve of the pressure of the dry air at Sitka; while in the region of the cold spring (the arctic regions of America) the maximum pressure of the atmosphere occurs, on the other hand, in spring."

Now, with all due deference to the opinions of this distinguished writer, I think the facts which he adduces to establish the generalization given above are by no means conclusive.

The "cold northwest winds that pass over Europe in the summer" are the exception and not the rule; "the east winds, on the eastern coast of northern Asia, (Udskoi,)" are east and southeast, and are therefore not directed towards central Asia; and on the western coast of the sea of Okhotsk, the wind during the summer is southwest, exactly from the central region, as appears

from the following extracts: And it is well known that the southwest monsoon prevails in summer all along the southeastern coast of Asia, and therefore not towards the central regions. Nor do the "northern winds on the coasts of the Siberian polar sea" reach the central regions as polar winds, but become irregular in intermediate latitudes.

At Nertchinsk, for instance, northeast of the great desert, the winds, according to Kupffer's tables, are prevalent northwest in the summer.

M. Becquerel says, page 311: "The etesian winds in the Mediterranean are a kind of monsoon; they blow from the north during the summer when they are the strongest, and in Egypt they blow even stronger from the south in the winter than from the north in the summer." "And in general," says M. Becquerel, "these monsoons, these winds that change with the seasons, blow towards the continents in the summer, and from them in the winter—that is, towards the parts which are most heated by the rays of the sun."

This seems to be the opinion of nearly all the meteorologists who have written on the subject. But the doctrine taught in these reports, and confirmed by facts, is, that the wind always blows towards the region of great rains in consequence of the great quantity of latent caloric evolved into the air by the condensing vapor in the formation of cloud; and when the wind blows towards a heated desert, it either stops in a region of rain before it gets there, or passes entirely across it, and produces rain on the other side; (page 100.) Butakoff, on the sea of Aral, says: "In summer the heat on shore is intolerable, and rain is a most unwonted curiosity. The air is purified only by the domineering winds, which, blowing almost constantly between W.N.W. and E.N.E., sweep away the miasma. These winds render the navigation on the sea of Aral very difficult; they rise and fall very suddenly."

From a journal kept west coast of the sea of Okhotsk between 54° and 55° N. the mean height of the barometer was 29.63 inches for the latter week in August. The temperature of the winters is mild; the large bays never freeze, except a little along the shore. During spring and summer the wind blows from the S.W. If it passes to the west or north it makes clear weather, and if to the S.E. it produces thick fogs; the east winds are habitually very strong. In autumn and winter the winds are from the S.E. or from the N.E. If they turn to the south, they produce foul weather; if to north, clear.—(P. 397, vol. 2, Ann. Hydrog.)

"At the northern coast of the sea of Okhotsk, according to observations made at an establishment of that name in about 60° north latitude during the months of June, July and August, the winds are generally from the S.E. and E.; they blow rarely from any other quarter." "During December till April the winds blow constantly from the N. and N.E., with clear weather."—(Ann. Hydrog., vol. 6, page 334.)

It would appear, then, from all the facts we have before us, that the winds seem to avoid the great desert in the central parts of Asia, on all sides except the west, which is largely the predominant wind in the middle latitudes of the northern hemisphere, as is clearly demonstrated by our own countryman, Professor Coffin, and on that side it appears from the maps that it is much hemmed in by mountains, and thus cut off from the rains which would be otherwise brought by the west wind.

189. The reader who is acquainted with the meteorological writings of Thomas Hopkins, of Manchester, may, perhaps, think I ought to except him from this category, as he has written a beautiful chapter on sun-heated land, and sea and land breezes, in which he has demonstrated that

the winds do not blow towards the centre of arid deserts, rising there and spreading outwards on all sides above. This statement, then, will do him ample justice on this point, and I will take this opportunity to say a few words as to the injustice with which this gentleman has repeatedly treated me and my theory.

In the winter of 1840 Mr. Hopkins published what he seemed to think a triumphant refutation of my manner of explaining the great Liverpool storm of the night of the 6th of January, 1839.

Mr. Hopkins says: Mr. Espy lately explained in this room, and still more recently at the meeting of the British Association at Glasgow, a new theory which he advanced. The theory is, that, from certain causes which he explained, the lower parts of the atmosphere in particular places moves upwards, leaving an approach to a vacuum in those places, which causes the adjoining lower portions of the atmosphere to rush in from all around towards the centre.

Mr. Hopkins adds, "Mr. Espy said the storm moved from the southwest of Ireland to the northeast of Scotland." And then he went on to argue that, according to my theory, the storm ought to have set in everywhere from the northeast; and after quoting a great number of accounts, he triumphantly adds, "there is no storm from the northeast mentioned in these accounts."

Not long after these objections appeared before the public, a reply was made by a gentleman of Liverpool; both the objections and the reply are given in my *Philosophy of Storms*, p. 471. I will copy here a paragraph or two from that reply:

"The principal objection made by Mr. Hopkins against Mr. Espy's theory of storms is predicted on a statement of Mr. Hopkins himself, which statement is not at all in accordance with Mr. Espy's views.

"Mr. Hopkins asserts that 'Mr. Espy said that the storm moved in a line from the southwest coast of Ireland to the northeast coast of Scotland.' I was much surprised on reading this paragraph, because I had heard Mr. Espy in his lectures here last summer strongly controvert the idea, that wide extended storms travel towards the northeast in this latitude and in the latitude of Pennsylvania; and as Mr. Hopkins referred to the explanation of the theory in question given by Mr. Espy at the late meeting of the British Association, I immediately turned to the report of his statement in the *Atheneum*, and found the following sentence in the very beginning of his paper. 'Mr. Espy commenced by stating that he had found in the great storm of the sixth and seventh of January, 1839, that the wind changed and the barometer fell sooner on the northwest parts of Great Britain than on the southeast; and from these two circumstances he thinks it highly probable that this storm moved not exactly towards the east but a little south of east; and if so, it would be similar to some of those storms which he had examined in the United States.' And Mr. Espy says in another part of his paper: 'As the wind in the first part of the storm is frequently southeast, and in the last part of the storm northwest, and as the barometer falls successively from the north of west to the south of east, it seems highly probable that these storms of oblong form move towards the south of east.' " The reply then goes on to show that, on the whole east coast of England, the wind was easterly or southeasterly at the very time there was a large space of calm in the middle parts of the island, and a violent westerly wind on the western parts, and that therefore the whole of Mr. Hopkins' reasoning on this point would go to confirm my theory if it had been truly stated by Mr. Hopkins.

Now, what does Mr. Hopkins do, after being convicted of stating my theory falsely, and argu-

ing from this false statement to prove that my explanation of the storm in question could not be the correct one? Does he attempt in any way to make the amende honorable? Let us see.

In 1854, Mr. Hopkins published a volume of 400 pages on meteorology, in which he states my theory falsely again, and proceeds to give a great many examples of storms, exactly contrary to the manner in which he states it. He says, page 97, "it appears, then, that the whirlwinds of Redfield and Reid may exist, and may be products of the ascending currents and converging winds of Espy—condensation of vapor being the primary cause of both. But here a new question arises, are all storms, as Mr. Espy maintains, produced by ascending currents alone? Mr. Espy contends not only that storms are the results of condensation, but also that they are horizontal converging winds rushing to a centre or central part where an ascending current exists, and that all storms are thus produced and are converging winds. Now, in so movable a body as the atmosphere, where one part so readily acts on another, it may be found that violent action of one kind may produce violent action of another kind. And if facts frequently observed in storms do not agree with the theory advanced by Mr. Espy, it may reasonably be suspected that some second cause is in operation, and we may endeavor to discover the particular action of that second cause."

He then proceeds to say, in page 101, "Captain Fitzroy, speaking of a 'pampero' near the mouth of the river Plate, says: 'on the 30th of January, 1829, the *Beagle* was standing in from sea towards the harbor of Maldonado. Before midday the breeze was fresh from the northnorthwest, but after noon it became moderate; and there was a gloominess, and a close sultry feeling which seemed to presage thunder and rain. During the three preceding nights banks of clouds had been noticed near the southwest horizon, over which there was a frequent reflection of very distant lightning. The barometer had been falling since the 25th slowly, but steadily, and on the 30th at noon it was at 29.4 inches, and the thermometer at 78°. At about three o'clock the wind was light, and veering about from the northwest to the northeast, and occasional lightning was visible even in daylight. There were gusts of heated wind.

"At four o'clock the breeze freshened up from the northnorthwest, and obliged us to take in all light sails. Soon after five it became so dark towards the southwest, and the lightning increased so much, that we shortened sail to the reefed topsail and foresail. Shortly before six the upper clouds in the southwest quarter assumed a singularly hard and rolled or tufted appearance, like great bales of black cotton, and altered their forms so rapidly, that I ordered sail to be shortened, and topsails to be furled, leaving set only a new foresail. Gusts of hot wind came off the nearest land at intervals of about a minute. The wind changed quickly, and blew so heavily from the southwest that the foresail split to ribbons, and the ship was thrown almost on her beam ends. The main topsail was instantly blown out of the men's hands, and the vessel was apparently capsizing, when topmasts and jibboom went close to the caps, and she righted considerably. Two men were lost. The starboard boat was stove by the force of the wind, and the other was washed away; and so loud was the sound of the tempest that I did not hear the masts break, though holding by the mizen rigging.

"Never before, nor since, have I witnessed such strength, or I may say weight of wind; thunder, lightning, hail and rain came with it, but they were hardly noticed in the presence of such a formidable accompaniment. After seven the clouds had all passed away, the winds settled into a steady southwest gale, with a clear sky.'"

"Now, are not all these facts such, or nearly such, as would be likely to occur if we supposed much rain to be formed, and first carried to a certain height in the atmosphere, from which it would descend by its own gravity, but projected by the expansion of the air that was taking place at a particular elevation in an ascending current. It could not be the centre of an ascending current such as is described by Mr. Espy."

Hopkins, page 103—"Captain Fitzroy says: 'At Port Waterfall, near Port St. Antonio, we noticed some extraordinary effects of the whirlwinds which so frequently occur in Tierra del Fuego. The crews of sealing vessels call them williwaws, or hurricane squalls, and they are most violent. The southwest gales, which blow on the coast with extreme fury, are pent up and impeded in passing over the high land, when, increasing in power, they rush violently over the edges of the precipices, expand, as it were, and, descending perpendicularly, destroy everything moveable. The surface of the water, when struck by one of these gusts, is so agitated as to be covered with foam, which is taken up by them, and flies before their fury until dispersed in vapor. Ships at anchor under high lands are sometimes suddenly thrown over on their beam ends, and the next moment recover their equilibrium as if nothing had happened.

"In the Gabriel channel 'the williwaws,' bursting over the mountainous ridge which forms the south side of the channel, descend, and, striking against the base of the opposite shore, rush up the steep and carry all before them.'"

And, page 105, Laird and Oldfield thus describe a storm on the Niger: "There is something awfully grand and impressive in the appearance of the heavens before a tornado. A dark mass of clouds collects on the eastern horizon, accompanied by frequent loud, but short, noises, reminding one of the muttering and growling of some wild animal in a voice of thunder. The mass or bank of clouds gradually covers one-half of the horizon, extending to it from the zenith; but generally before this a small and beautifully formed radiant arch on the verge of the horizon appears, and gradually increases. Long before it reaches the vessel, the roaring whistle of the whirlwind is heard, producing nearly as much noise as the peals of thunder that seem to rend the very clouds apart from each other. The course of the squall is distinctly marked by the line of foam it throws up, and I have stood on the taffrail of the vessel and felt the first rush of the wind, while her head-sails were becalmed. The sensation it produces afterwards is cheering and delightful. From breathing a close and murky atmosphere, loaded with unpleasant vapors that invariably precede the tornado, the mind becomes relieved, as it were, from a load, the air is fresh and clear, and everything around is exhilarating."

"Can such a storm as this arise merely from the expanding or rushing of air into a vacuum?"

I might give other examples of a similar nature, but certainly enough have been quoted to prostrate my theory in the most signal manner, if it is such as Mr. Hopkins asserts it to be.

But what will be the astonishment and indignation of the reader when he learns that I assert the very thing which he says I deny, that the air does blow outwards at the surface of the earth from the falling rain, in particular cases. Almost at the beginning of *Philosophy of Storms*, page 7, where I am announcing my theory, I say: "If the dew-point should be much below the temperature of the air, the visible spout or cloud will not reach the surface of the earth, and then the rain, falling through the lower atmosphere, may, partly by its impulse and partly by its cooling influence, (thus increasing its specific gravity,) cause the air at the surface of the earth to move *outwards* in all directions from the centre of the shower, especially in front,

while all the time the air at some distance above is running inwards from the circumference of the cloud at its lower borders, and, of course, upwards in the centre, and outwards in the upper parts. If we suppose the dew-point to be 20° below the temperature of the air, we shall find, by calculating according to the law, (Article III,) that the lower borders of the cloud will be a little more than twenty hundred yards high; and when the dew-point is nearer the temperature of the air, the cloud will be nearer the earth at the lower extremity. This reasoning applies to clouds of moderate size.

“But if the cloud is of great size, then the supply of air to keep up the ascending column cannot be afforded without reaching down to the surface of the earth, even when the lower part of the cloud may be at a considerable distance above the surface of the earth. Thus the law will become general, that *in all very great and widely extended rains or snows, the wind will blow towards the centre of the storm.*” That the wind does not always blow towards the centre of storms that are not very great and widely extended, is implied in this generalization, even if it had not been expressly declared in the previous paragraph.

Again, at page 74, speaking of the manner in which cumuli are formed in a summer's day until finally one produces rain, I say, then, “the descending rain cools the air below the cloud and causes it, by its greater specific gravity and also by the weight of the drops of rain, to move outwards in all directions from the centre of the rain.”

Again, at page 140, speaking of a wide extended snow storm, I say: “If we conceive the action very great as it is in all summer hail storms, in which the drops of water are carried up to a great height and frozen, the snow might not be permitted to fall down where it was generated, but be carried off to some distance from where it was taken up, and thrown down in such quantity as to cause, by its weight and cooling effect together, the wind to blow outwards in all directions from its place of descent. Many such places might be formed in a storm of five hundred miles in diameter, and, of course, many irregularities be produced similar to the one in question. These particular, violent, up-moving currents and downfalls of snow by their side would be likely to occur in the neighborhoods of hills and mountains. For the air, rushing in towards the centre of the general storm, on coming to a hill will glance up it, and having acquired an upward motion, will be inclined to continue it, and thus produce the effect in question. And if the hill is very lofty, as the Himalayas, the snow will be thrown down on the windward side, but if it is of moderate elevation the snow may be thrown down on the leeward side. In the former case, the wind may be forced down the side of the mountain on the windward side at the surface of the ground, whilst a few hundred yards high it may be blowing up the mountain over that at the surface of the earth, blowing downwards. It is also known that a violent summer shower often causes the wind to blow outwards in all directions from the falling shower, when a few minutes before it had been blowing the contrary way towards the forming cloud.”

Again, at page 151, speaking of this same cumulus, I say: “When the top of this cloud rises to a very great perpendicular height, the barometer under the base sinks proportionally, and the upward motion of the air in the middle of the cloud is sometimes so great as to carry the drops of rain above the region of perpetual congelation, and throw them out on both sides of the cloud frozen into hail. Does hail of great size ever come down through the base of the cloud? And when a summer cloud begins to rain down through its base, does it always stop the

upward current in the middle of the cloud, and finally invert it, causing the air to move downwards in the middle of the rain and outwards at the surface of the earth, contrary to the motion it had inwards while the cloud was forming? Or does the air sometimes, even after the commencement of the rain, continue to run in under the base of the cloud round the borders of the rain, glancing up over the air pressed downwards in the centre and outwards at the surface of the earth, by the weight of the rain and its cooling effect on the air through which it passes?"

Again, page 156, I say: "When a thunder storm passes in sight note the phenomena. Not unfrequently the barometer rises in the borders of the storm, and, during the rain or hail the wind blows outwards from the centre of the shower. It is very desirable to know to what distance this outward wind and rise of the barometer reach, and what effect it has in generating new clouds by the warm, moist air blowing up over it. The dew-point frequently, by this outspreading of the air below, reaches an observer at some distance from the rain, and thus becomes a forerunner of an approaching shower, generated in the manner indicated above.

"If a mountain were suddenly elevated by volcanic agency across our country from northwest to southeast, it would become the immediate cause of rain, by the air rising up over it as it blows from the southwest. Every thunder shower produces a mass of cold, heavy air, through which the drops of rain or hail have passed, tending to produce a new shower on the windward side of this cold mass, just as a mountain would do. To investigate all the phenomena of this summer shower forms no inconsiderable part of our present object."

Again, at page 15, I say: "On the 19th of June, 1835, about five p. m., there took place in New Jersey a most violent landspout. It appeared to all persons, in whatever direction it was viewed, in the shape of an inverted cone of cloud, reaching from a dark cloud above down to the earth. It commenced about seven miles west of New Brunswick and terminated at Perth Amboy, about seventeen miles from where it began, having traveled a little north of east, with a very moderate velocity, not exactly ascertained, probably not more than twenty-five or thirty miles an hour. It prostrated everything in the path which was from two hundred to four hundred yards wide; the trees on the north side being almost all thrown with their tops towards the southeast, and those on the south side with their tops to northeast, and none with their tops outwards, as appears by a chart exhibited to the American Philosophical Society by Prof. Bache. It unroofed the houses and prostrated their walls, many of them outward, as if by explosion, and some light ones it lifted up nearly perpendicularly to a considerable height, and tore up the floors of some whose walls were left standing. It carried the joists and upper floors and rafters in some instances to a considerable height, and threw them down on the north side of its path four hundred yards from the house, almost at right angles to its course, and exactly opposite to the course the wind was blowing at the ground in the yard, as manifested by the direction in which the trees were lying. It carried off shingles and hats and books, and various garments, and branches and leaves of trees, and other light bodies, and threw them down on the north side of the spout, in a band of about four or five miles broad, terminating on the northeastern side of Staten Island, about fifteen miles from Amboy where the spout ceased to reach the earth, and twenty-five from where it took up the shingles. It threw these materials down *along with a severe shower of hail and rain*. These materials were seen to fall with hail and rain by a great number of witnesses, whom I examined during the week which I spent investigating this spout.

There was no hail and rain, at least as far as I could learn, on the path of the spout, it began about a mile on the north side of it, and became heavier a little further still, and then gradually diminished again as it approached the northern border. The hail was confined to the middle of the band.

Three patches were found nearly circular, with diameters equal to the width of the spout, with the tops of the trees all thrown inwards towards one common centre. In the middle of one of these stood a large house, which had its roof carried off, and the trees all around the house had their tops thrown towards the house. The walls of the upper story, both on the north and south sides, were cracked, and in one crack was thrust a lady's handkerchief, and in the other a sheet, which had been taken up from a bed in the room, and the cracks closed when they were carried partly through.

These facts leave no doubt that there is an upward motion of the air in the spout, and an inward motion below, and the fact that the hail and shingles fell together, makes it equally certain that this hail had been formed from drops of rain carried up by the spout above the region of congelation, and then thrown down along with the shingles carried up at the same time. The wind had been southwest all day, which, no doubt, was the reason why all the shingles fell to the northeast of the track of the spout. There are many other highly interesting particulars connected with these spouts, which will be detailed in subsequent pages. I will only add, that the evidence which I collected was conclusive, that, at the time of the falling of the hail, the wind on the northern border of the shower was strong from the south, and on the southern border of the shower strong from the north. This is a fact which will of itself explain why in many showers the wind at the *surface* of the earth blows in all directions from the centre of the shower, and yet a few thousand feet high it *may* be blowing in the under part of the cloud on all sides towards the middle of the cloud. This phenomenon I have more than once seen.

In the 17th vol. of the Franklin Institute, for 1836, page 392, I have given a diagram of a storm-cloud, with the rain coming down from its base, with arrows showing the direction of the wind blowing outwards in all directions at the surface of the earth from the falling rain; and a calculation is made on the supposition that the air is cooled ten degrees by the falling rain from the height of one thousand feet down to the surface of the earth, that then the velocity of the air outwards, from its greater specific gravity alone, would be sixty-two feet per second. I ought not, however, to presume that this calculation was seen by Mr. Hopkins.

In page 552 I have attempted to explain, hypothetically, a most remarkable phenomenon called the helm wind of Crossfell, described by the Rev. J. Watson, in the eighth report of the British Association.

"This name is applied to a very violent wind blowing frequently from some eastern point of the compass at the west side of the Crossfell range, and confined, both in length and breath, to the space between the helm and helm bar. The western front of the helm is a long, large roll of clouds, clearly defined, and quite separated from any other cloud on that side.

"The bar has its eastern front as clearly defined, and at the same height. On the west side of the bar there is either no wind, or it blows in a contrary direction—that is, from the west.

"Neither the helm nor the bar are separate or detached clouds, but rather the bold clearly defined fronts of clouds, extending eastward behind the helm, and westward from the bar.

"The open space between these clouds may be called a very flat ellipse, eight or ten, or even

twenty or thirty miles long, and from one-half to four or five miles wide. They appear always united at the ends.

"The open space between the helm and bar is clear of clouds, with the exception of small pieces breaking off now and then from the helm, and driving over rapidly to the bar; through this space is often seen a higher stratum of clouds quite at rest. It is seldom accompanied with rain in the open space, and never continues long after it begins to rain heavily."

Then I go on to say: If it should be ascertained that it rains on the top of Crossfell at the time of the helm wind, it would be easy to explain all the phenomena mentioned above. The weight of the rain, and its cooling effect under the helm cloud, would depress the air under the cloud, and press it out on all sides with a velocity proportional to the height from which the drops descend. This outward motion of the air below would not reach to any considerable height, and the air above would be running towards the helm cloud, and upwards in that cloud, to supply new vapor to be condensed into cloud by the cold of diminished pressure. The air which rushes out from the falling rain below, meeting that which was coming from the west, would soon be stopped in its motion outward, and in rising up would form the helm bar; and as it rushed out from the very bottom of the helm cloud itself, it would carry with it portions of that cloud towards the bar. Up in the regions of the bar, the air at the same time would be in motion towards the helm, and would carry portions of that cloud over in that direction with it.

If this is the true explanation, several other facts, besides those mentioned above, will be found to exist at the time: Rain under the helm cloud; a colder air between the helm cloud and the bar than to the west of the bar; a smaller difference between the dew-point and the temperature of the air between the two clouds than on the west of the bar; the top of the bar vastly lower than the top of the helm cloud, though their bases may be on the same horizontal level; the cloud that passes from the helm to the bar, underneath the one that passes from the bar to the helm; the edges of the bar seldom if ever so well defined as the edges of the helm, and never so dense, nor so free from motion; the lower part of the bar and the upper part of the helm, which cross over to each other, and frequently a jutting out of the upper part of the helm cloud so as to overhang the bar. If these phenomena do not accompany the helm wind, then the above is not the true *rationale*; if they do, it is.

It may still be asked, why the bar cloud, when once formed by the upward motion of the air, dissolves, in a great measure, on being pressed or driven towards the helm cloud by the motion of the air in that region?

The answer is, that the air curves downward in going from the bar to the helm, as it does in passing across a hollow between two mountains, and in coming under greater pressure the cloud is dissolved.

These extracts from my Philosophy of Storms are sufficient to show how utterly unfounded was the assertion of Mr. Hopkins, that "Mr. Espy contends that all storms are converging winds."

Having now demolished me and my theory to the entire satisfaction of his readers, as he no doubt thinks, Mr. Hopkins utterly ignores me and all that I have done to the end of his book, and goes on with the utmost coolness to explain some of the most important meteorological

phenomena, according to my theory, as if he was the first who ever thought of the principles employed in the explanation.

Hear him; in page 109 he says: "As the column of mercury in the barometer balances the weight of the atmosphere which rests upon it, the height of the mercury must exhibit the amount of that weight. But the height of the column alters so much from time to time as to make the extreme range of the alterations at the level of the sea about three inches; and, of course, the weight of the aerial column must vary to the same extent. Now, what is the immediate operating cause of this variation in the weight of the atmosphere? This is a question which has been often asked without any satisfactory reply having been given, though many attempts have been made to answer it. There are many localities on the surface of the globe where the heat, which has been taken up by evaporation, is freely given out by condensation where much rain falls, but none where the effects are of a more striking character than in the neighborhood of Cape Horn.

"The solar heat taken up by the water of the Southern ocean is, in the form of vapor, conveyed to the mountains of Tierra del Fuego, and is there, by the condensation of vapor, when copious rain falls, liberated and left to attach itself to that portion of the atmosphere with which it is in contact, to raise its temperature and cause it to expand. The way in which this liberated heat expands the atmospheric gases has been explained in a paper on the formation of the cumulus cloud, published in the Philosophical Magazine for August, 1841.

"It was there shown that the liberated heat increased the elasticity of the gases, caused them to expand into a wider space, pushed the adjoining mass of air away, raised that which was above, and caused it to flow over to adjoining parts, and thus removed a portion of the weight of the atmospheric column in the locality. This is what apparently takes place in the part of which we are speaking—the southern extremity of America, where rain falls freely. Now, if such causes can so affect the barometer in this part of the world, may we not infer that wherever that instrument is similarly affected, causes similar in their nature may possibly have produced the results?"

On reading the above explanation of the great fluctuations of the barometer, and the manner in which cumulus clouds are formed, and the air in them expanded by the heat liberated from the condensed vapor, who, unacquainted with my labors, would not think that the whole method originated with Mr. Hopkins?

But the reader will see by the extract given in a note from the paper read before the British Association mentioned above, that the answer here given by Mr. Hopkins to the question, what is the cause of the great fluctuations of the barometer? which he says was never answered before, is identical with mine, so far as the principle is concerned, but lamentably defective in leaving out the calculation of the exact amount of power developed by the caloric evolved by the condensed vapor; for the great strength and beauty of the theory depend on its power to make this calculation.

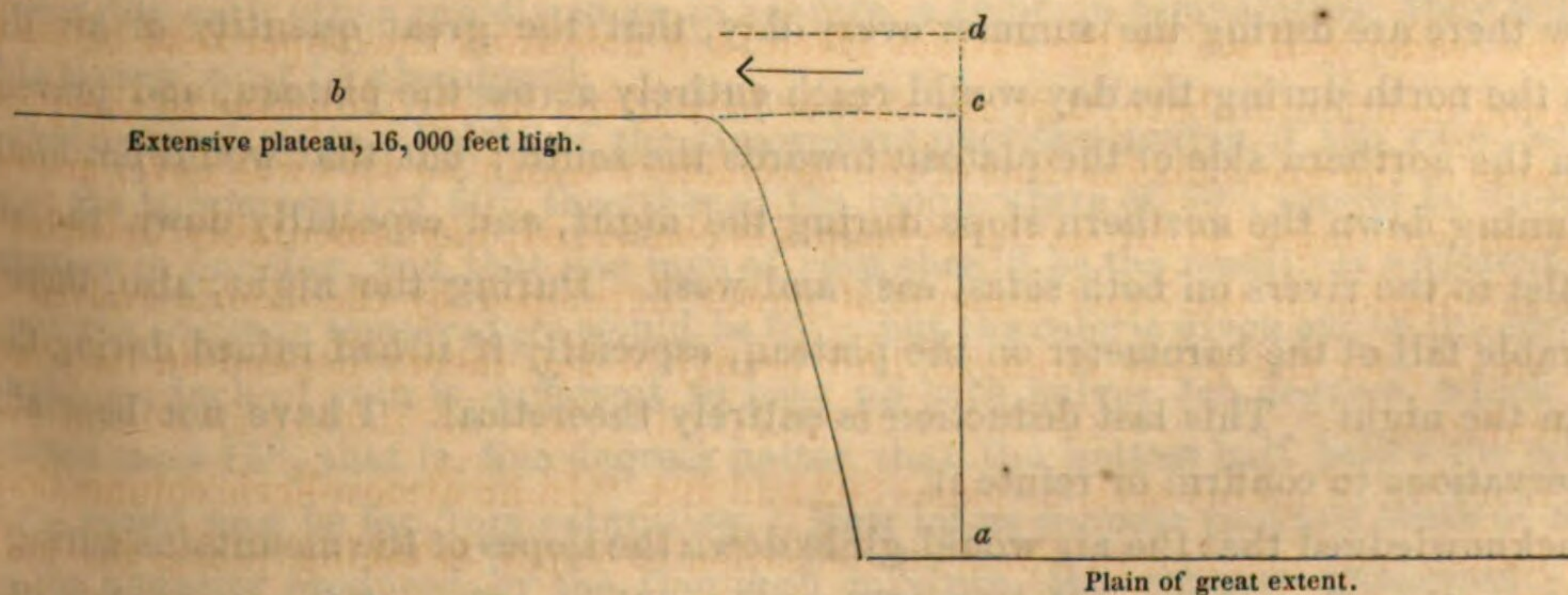
It is true, Mr. Hopkins says, at pages 302 and 304, "In an atmospheric column that is ascending to higher regions, and in which condensation of vapor is taking place, the heat liberated reduces the cooling on an average to about one-half of what it would otherwise be; and at the height of 10,000 yards the difference of temperature between the clear and clouded atmospheric

columns produced by the condensation of vapor is no less than 50° , and with a force proportioned to that difference would the colder column be disposed to press up the warmer."

But the author does not at all show what that force is; nor does he anywhere in his work say how he obtained the law of cooling in moist air when compared with dry—a law which I obtained by a most laborious set of experiments with the nephelescope. The reader is, in fact, left to suppose that it is a conjecture of his, and therefore that it may be very far from the truth. To do the author justice on this point, he has stated, in page 306, a modification of this law, which is entirely his own, and that is: when the cloudy column in its upward motion reaches a height where its temperature is 32° , it will then remain at 32° , however high it may go, even to the distance of 10,000 yards, being kept at that temperature by the congelation of the water condensed into cloud by the cold of expansion. He says: "These two processes—first, condensation of vapor, and, secondly, congelation of water—being successively and rapidly repeated in a column ascending to a great height, would keep the whole mass at 32° as long as vapor remained to be condensed and frozen." In making this statement, the author went "on his own hook," and came to a conclusion entirely at variance with my calculations on the same point. I have shown that all the vapor in air at the temperature of 32° , if condensed in it, would prevent it from cooling in its upward motion only 20° by condensing into water, and by freezing only $2\frac{1}{4}^{\circ}$ more; and, besides, if air was to remain at the temperature of 32° all the way up to where it would expand into double the space from diminished pressure, not only no vapor would be condensed in its motion upwards, but the air then would be capable of holding exactly twice as much vapor as it could below, in consequence of its occupying twice the space at the same temperature. If Mr. Hopkins had studied my calculations on these points sufficiently to understand them, he would have been spared the mortification which he must feel in discovering, if he ever does discover, the suicidal character of this enunciation.

In note 73 I have given an extract from the introduction of my *Philosophy of Storms*, not merely to show how unjustly I have been treated by Mr. Hopkins, but to let the reader see the clearness with which the theory was developed in one of the earliest papers that was written on the subject.

190. Mr. Becquerell, p. 346, gives a theory of the winds by M. Saigey, which, however unsatisfactory and erroneous when applied to the trade winds and monsoons, will, I think, satisfactorily explain mountain winds and land and sea breezes under one category.



Indeed, if it shall be found that very low flat islands, or very low flat seacoasts of continents have no sea breezes, or at least very feeble ones, then I think the theory will explain the phenomena satisfactorily. To illustrate the principle, let us take as an example the Hima-

layas, and the lofty table land of some hundred miles in extent, *b*, contiguous to the wide plain of Hindoostan, sixteen thousand feet below, *a*. Let us suppose that at the rising of the sun there is no wind either on the plain below or plateau above. Now, we know that the atmosphere is not absolutely diathermanous even to the rays of the sun, and that, therefore, the whole mass of the air from the surface of the earth to the top of the atmosphere is heated many degrees by the sun in the morning, and of course expanded. Suppose, some time after the sun rises, the whole column of air *a c* over the lower plain is heated one degree; having been at the mean temperature of 52° , it will be expanded upwards one five-hundredth of its whole height, $\frac{1}{500}$ of 16,000 feet = 32 feet; and when the air is heated 2° , the column over the lower plain will be elevated 64 feet above the level of the upper plain, and the same difference, or a little greater, will exist at the top of the southern Himalaya, and therefore the head of pressure on the south of the mountain top will be equal to 64 feet greater than on that over the upper plateau, which will cause the air to flow over the top of the mountain towards the plateau with a velocity of 64 feet per second, according to the law of spouting fluids; and when the temperature of the column is increased eight degrees, and expanded to *d*, the head of pressure would be 256 feet—that is, *d c* is 256 feet—which would give a velocity of 128 feet per second towards the plateau. If the plateau is of great extent, the velocity of the air over the mountain upon it might increase with the increasing temperature to near the hottest part of the day. During all this time the barometer would rise on the upper plateau, even after ten o'clock, when it begins to fall on the plain below. The strength of the wind on the top of the mountain, and the rise of the barometer on the plateau, would be greatly increased if great clouds should form at the same time on the southern slope of the mountain in consequence of the great increase of heat by the evolution of the latent caloric of the condensing vapor. In either case, at the time of greatest heat, there will be an abnormal quantity of air over the plateau, and when the air over the lower plain contracts by cold in the night, the head of pressure from the plateau will be greater than over the plain, and the current will be inverted. And as the air in contact with the ground is several degrees colder in the night and warmer in the day than the air some yards above, there will be a current down the slope in the night and up the slope in the day, at least on the south side of the mountain. And if the circumstances on the north side of the plateau were the same as those described on the south, the air during the day would flow towards the plateau, and in the night from it. It would seem, however, if clouds should be formed on the south side, as we know there are during the summer every day, that the great quantity of air driven over towards the north during the day would reach entirely across the plateau, and prevent the flow of air on the northern side of the plateau towards the south; but that would not hinder the air from running down the northern slope during the night, and especially down the slopes that give outlet to the rivers on both sides, east and west. During the night, also, there will be a considerable fall of the barometer on the plateau, especially if it had rained during the day and ceased in the night. This last deduction is entirely theoretical. I have not been able to find any observations to confirm or refute it.

It is acknowledged that the air would glide down the slopes of the mountains during the night merely from the effect of the radiation of heat from the surface of the ground cooling it, and the air in contact with it, in many cases ten or twenty degrees below the normal temperature;

but the effect from this cause in the case of extensive table lands would, I think, be very feeble compared with the other.

So in the case of the great table land of Mexico, seven thousand feet above the level of the Pacific on one side, and the Gulph of Mexico on the other, it ought, when not prevented by general winds, to have on both its eastern and western slope sea breezes every day and land breezes every night, and in the rainy season there ought to be rains every day, with cessations in the night.

191. During the time of these rains it ought to be abnormally hot near the borders of the rain, on that side of the rain over which the upper current of the air passes from the top of the cloud, because near the outer borders of the cloud the upper air will be abnormally warm from containing the caloric just liberated by the condensation of the vapor in forming the cloud, and while it rains constantly in one locality it will prevent rains from taking place at all for some considerable distance on that side over which the upper air passes from the rain cloud, because up-moving columns of air cannot rise in it until it has radiated off much of its abnormal heat. This is the reason why it hardly rains in the region of the regular trade winds, even on the ocean, where there is great evaporation; and as the great Sahara is in that region, it cannot rain there only in places where there are mountains, which are found to be more numerous than was formerly thought. So it cannot rain much on the leeward side of lofty mountains, as on the western side of the Andes, in the torrid zone, nor on the eastern side of the Andes south of 30° , nor in the great desert of Gobi, being the region over which the air from the top of the great cloud of the Himalayas passes in the summer, having deposited on the south side, before it reached the top, two-thirds of its vapor, as was shown before. It is known that in some places three and four, and even five hundred inches of rain fall on the south side during the summer months; a quantity, in the last case, sufficient to heat up the whole atmosphere over which the rain fell, by the heat liberated from the condensing vapor, 5000° of Fahrenheit; for one inch of rain being the one four-hundredth of the weight of the whole atmosphere over the region where it fell, the vapor condensed to form it would liberate latent caloric enough to heat four hundred times its weight of air ten degrees.

192. If those who believe that clouds and rain are produced by the intermixing of masses of saturated air of different temperatures will institute an enquiry what might be done by this means under the most favorable circumstances, allowing even, what is not true, that large masses of air can penetrate each other rapidly so as to acquire a common temperature, they will soon find that this theory must be abandoned.

Suppose that as much as two halves of the atmosphere over the region of the rain, both saturated, one at the temperature of 60° , the other at the temperature of 70° , should be thoroughly mingled together in one day, and that one inch of rain should be the result. If no latent caloric was given out, the common temperature would be 65° ; but the caloric given out by the condensed vapor to make one inch of rain is sufficient to heat up both halves ten degrees, which would make the mixed mass 75° , that is, five degrees hotter than the hottest half before the mixture, so that the air would now be far from saturation. Now let us suppose that one tenth of an inch of rain was the quantity produced by the thorough mixture, the common temperature of the mixture, if no latent caloric was given out, would be as before, 65° , but the caloric given out by the vapor sufficient to produce one tenth of an inch of rain is sufficient to heat both halves one

degree, so that the temperature of the mixture would be 66° ; and by turning to a table of dew-points, it will be seen that the elastic force of one atmosphere of vapor at 66° is more than the elastic force of the two halves, one at the temperature of 60° , and the other at the temperature of 70° . And even if no latent caloric at all was given out by the condensing vapor, and the mingled mass should assume the mean temperature of 65° , it will be found by the table of dew-points that even then only .007 inch of elastic vapor would be condensed, not enough to make seven one-hundredths of an inch of rain.

Besides, where could masses of air differing in temperature ten degrees be found in any of the regions of great rains, except the belts in the ocean near the polar circles? and there the air which comes from the poles is almost destitute of vapor, and so far as it mingles with the air which meets it from lower latitudes, it diminishes the quantity of rain which would otherwise fall.

Again, where can be found great masses of air, entirely or even nearly saturated with vapor? The dew-point of the air over the ocean, even in warm climates, is seldom found nearer than four or five degrees of the temperature of the air, not unfrequently at ten or twelve, and in Hindoostan sometimes fifty or sixty. In fact, the air is seldom saturated with moisture, even in the midst of rain, and never in the midst of down-moving and, of course, dissolving clouds, which are always found to be at a lower temperature than surrounding air, which is caused by the cooling effect of the evaporating of the particles of water composing the cloud.

193. As to those who think that rain is produced by the cold of mountain tops as the air passes over them, in the first place, this theory does not explain how rain is produced over plains. And secondly, it is known that air in passing over high mountains, such as the Himalaya or the Andes, is twenty or thirty degrees warmer than the atmosphere is at the same height over plains, because on passing over them it has the latent caloric in it, just evolved by the condensation of the vapor on the windward side, making it ten degrees warmer for every tenth of an inch of elastic vapor condensed than it would be in rising to the same height without vapor in it to condense.

Besides, if the mountain top was so cold as to cool the air passing over it below its dew-point, the cloud thus formed would be a thin stratum touching the ground as a fog.

194. Indeed, so great is the quantity of abnormal heat sometimes carried over a mountain from a great rain on the windward side, that I venture here to give a hypothetical explanation of a hot wind called *sirocco*, which is sometimes felt in the northern part of Sicily and Italy.

It is generally thought that this wind originates on the heated desert of Africa, some thinking it blows across the Mediterranean as a horizontal wind, and some, that it rises over the desert and descends at the place affected.

As to the first opinion, it appears to me impossible, for two reasons; first, nothing could cause a hot wind to blow away to a colder region but a great condensation of vapor and rain, in the region to which it blew, and nothing of the kind appears in evidence at the time; second, in blowing over the Mediterranean for several hundred miles it would be gradually cooled, and even in crossing over Sicily it would be cooler on the north side than on the south; but such is not the fact, for it is particularly oppressive at Palermo, on the very northern coast. And as to its coming down from above, there are also two objections, nearly equally valid. First, if it ascended over the hot regions of Africa, and flowed to the north, it would radiate off much of

its abnormal heat before it would reach these distant localities, and might come down as a dry wind rather cold than warm; and if it did not radiate off most of its abnormal heat it could not sink through air of greater specific gravity than itself.

The explanation that I suggest hypothetically is, that at the time of this hot south wind there may be a great rain taking place on the other side of a mountain to the south of the observer, sending its hot air over above, and radiating its abnormal heat down, and even bringing some of the hot air down the slope on the north, which would be felt there as an excessively hot, dry air, and on the ceasing of the rain would terminate as suddenly as it commenced.

All round the borders of a great sudden rain, even beyond the outspread cloud above, there is always a considerable increase of heat, which in very hot climates is felt as very oppressive; but in very cold climates it only produces a pleasant mild day before the storm of snow.

If it shall be found by observation, which this hypothetical explanation is intended to produce, that there is such a rain on the south, then, I think, the hypothesis will be theory. If no such rain occurs, the true explanation has not yet been given. On this subject the following facts are highly interesting. The distinguished philosopher, Captain Lefroy, in the *Magnetic and Meteorological Observations*, page 139, says: "A local phenomenon of interest was observed several times at Fort Simpson, just east of the Rocky Mountains, in the rapid rise of the thermometer when the wind changed from southeast to southwest. It appeared as if the warmer air of the Pacific ocean were transferred, across the neighboring ridges of the Rocky Mountains with little loss of temperature. For instance, on the 25th of April, with such a change of wind, the temperature rose in one hour from $43^{\circ}.5$ to 58° Fahrenheit."

Professor Guyot told me that "he has frequently known it to rain on the northern slope of the Alps several thousand feet above the base, when, at the same time, the air below was many degrees below the freezing point, and that, on ascending from the valley below, he suddenly came into a warmer air, and at this time the wind was blowing from the south, producing great rains on the middle slope of the Alps and snow above." I think, if all the rain and snow had come down on the south side of the mountain, the air coming over the top would have been much warmer on the upper part of the northern side.

Professor Coffin, in his *Winds of the Northern Hemisphere*, page 104, gives an extract from a letter of Rev. Justin Perkins, residing in Persia. He says "my residence is on the northeastern declivity of a high mountain. There are some important causes affecting the winds in this province, which I will state; about once a month ordinarily we have a strong wind, often violent, from the *west*, which is the *simoom* or *samiel* from the Arabian desert. It usually continues about three days; and though its noxious properties are much neutralized by its passage over a distance of hundreds of miles, and across the high snowy Koordish Mountains, it is still warm and often *hot* here, and very debilitating to men and animals, and it is often so dry and hot here as to wither and crisp vegetables. The daily lake (*Ooroomiah*) and mountain breezes continue during the warm part of the year with great regularity, except when interrupted by the *simooms*, usually once in four, five, or six weeks. During this part of the year there is also much uniformity in the weather, a cloud seldom appearing in the sky." *Ooroomiah* is in latitude $37^{\circ} 30'$ longitude $45^{\circ} 10'$ east.

Of this particular case of *simoom*, I think, but one explanation can be given in the present state of science, and that is, a great rain on the west side of the lofty mountain to the west of

the observer, who lived on the eastern slope. If it shall be found that rain does not take place there at the time, then the true explanation of the phenomenon has not yet been given.

Brydone, in his tour through Sicily and Malta, speaking of the sirocco, says: "It can hardly come from the scorching sands of Africa, or it would be most violent on the southern side of Sicily, which is not the case." He adds, however, "it is possible that its heat may be increased by its passage across the island, for it is ever found much more violent at Palermo, (which is the most northern point,) than anywhere else in Sicily."

He says: "At Palermo on the 6th and 7th of July, the thermometer did not rise above $72\frac{1}{2}^{\circ}$, but on the morning of the 8th the sirocco had set in, and on taking the thermometer out to the open air it rose to 110° , and soon after to 112° ."

"The barometer was but little affected, it had fallen only about a line. The sun did not appear the whole day, otherwise the heat would have been insupportable."

"This extraordinary heat continued till three o'clock P. M., when the wind changed at once almost to the opposite point of the compass, and all the rest of the day it blew strong from the sea. The sudden change from heat to cold was almost as inconceivable as that from cold to heat. The current of this hot air had been flying for many hours from south to north, and I had no doubt that the atmosphere for many miles around was entirely composed of it; yet the wind no sooner changed to the north than it felt extremely cold; in a short time the thermometer sunk to 82° ."

It seems probable that this hot sirocco is a very dry wind, for the author says that "when he was sheltered from the wind he felt but little inconvenience from the heat, and although the perspiration was violent it was attended with only a slight moisture on the skin."

I have no facts to show that there was a rain to the south at the time of this sirocco, but as it was very cloudy at the time it adds to the probability that there was. It appears from the maps that there is a mountain to the south of Palermo.

Many examples might be given of very great heat in the neighborhood of great rain. In Dr. Young's Lectures, vol., 2. p. 453, it is said: "At Cawnpore, northwest of Calcutta, near the mountains, from the 14th of April till the 6th of May, 1789, the mean temperature without doors at 2 P. M. was 127° ; the greatest heat, 18th April, 144° . The mean heat at night was 93° ; behind a wet mat the mean heat at 2 P. M. was 79° , that is, 48° below that in the open air." At this time the rains had not commenced at Cawnpore, but they had further south.

Mr. Murchison, in his address before the Geological Society, 1852, says: "My friend Professor Oldham, in writing to me from Chusra Poonjee, in the Khassya hills, north of Calcutta, states that the rain fall is there about six hundred inches per annum, 550 of which descend in the six rainy months, beginning in May; and that in one day he measured a fall of twenty-five and a half inches. This remarkable phenomenon, it appears, was known to Drs. Hooker, Thomson, and other scientific men."

At the foot of the Himalaya April is the warmest month in the year; after the rainy season has commenced, on the Western Ghauts, at one place, Ambala, about latitude $30^{\circ} 25'$, the mean temperature of the month of May at ten o'clock is 100.—[Dove.]

At the same time the Deccan, just east of these same Ghauts, is excessively hot without rain.

In the summer, while it rains much every day among the mountains of Abyssinia, it is excessively hot without rain on the Red sea and its borders, in the vicinity of the rains.

Captain H. Strachey, of the Bengal army, says: "The climate of Ladak, north of the Himalaya, is sufficiently fine, as regards the proportion of sunny to cloudy weather. Winter is the season of most clouds and least wind. In Central Ladak a good deal of high west wind prevails in spring; and in the southern districts next the Indian Himalaya strong south winds blow during the day—often very violent in exposed situations. By far the commonest form of cloud is a cirrus, of a hazy indefinite sort; cumulus may be seen, but rarely, in summer. The nimbus, as seen in the lower regions, is almost unknown here, or faintly approached in midsummer, and seldom perfected in a few drops of rain. The discharge of snow, which never amounts to much, results from a thin misty cloud, formed by insensible gradations from the cirrus, condensed and lowered to the surface of the earth; the descent of such quasi-nimbus into the valleys as low as Central Ladak, or 11,000 feet, during the daytime, occurring only twice or thrice in the course of a winter, and never at any other season. These statements must not be applied very strictly to the southernmost parts of the country, as they partake, in a slight degree, of the clouds and mists of the Indian Himalaya.

"Speaking approximately, one may say it never rains in Ladak; and what little snow falls, nearly all occurs between midnight and morning, during the winter and spring."—(Journal Royal Geog. Society, 1853, page 66.) Foissac, vol. 2, p. 88, quoting Boussingault, says: "In Peru, 5° south in the valley of the Andes, between 4,000 and 5,000 feet high, it rains much more in the night than in the day."

In December it rained but 2^{mm} in the day, and 150^{mm} in the night. R. Strachey, esq., of the Bengal Engineers, in the 21st vol. Royal Geog. Society, says, page 73: "The winds in the mountains of the Himalayas blow up the valleys during the day from 9 A. M. to 9 P. M., and down them during the corresponding hours of the night. At the debouches of the principal streams into the plains these night winds blow with great violence, particularly in the winter. They diminish in force as we ascend the mountains, and at great elevations, and in the plains of Western Thibet the nights are almost always perfectly calm. The diurnal winds, on the other hand, in the latter country, are terrific; and in travelling there we looked forward to the afternoon, when the winds are at their height, with real dread. The winds, so far as we had an opportunity of observing them in this part of Thibet, commenced in the S.E. quarter about 9 A. M., gradually shifting round with the sun to the S. W., and ended in that quarter about 9 P. M. On several occasions I have noticed the wind blowing very faintly from the N. early in the morning; and in the plains of India, during the prevalence of the hot northwesterly day winds, which are succeeded by a night almost calm, a very light air from the E. is observed sometimes early in the morning.

"The influence of the summer rains extends into the country beyond the great snowy peaks in a very limited degree, each successive ridge stopping a portion of the moisture; and the country behind the higher summits of the range becomes rapidly more arid; and when at last we reach the Thibetan plain, we find it little better than a desert. This plain is north of the British Himalayan provinces, and is about 120 miles long N.W. to S.E., and from 15 to 60 miles broad, with an elevation of from 15,000 to 16,000 feet. The Sutledj flows through the middle of it.—(Journal Royal Geog. Society, 1853, page 67.) The snow in Ladak is remarkable for its form as well as its small quantity; it falls in minute granules, and is analogous to the fine drizzling rain of summer in the higher regions of the Indian Himalaya.

"Dew, hoar frost, and hail, are, I believe, unknown, unless in the immediate proximity with the Indian Himalaya.

"The total absence of thunder and lightning in Ladak is most remarkable, and appears to be dependent on the excessive dryness of the climate. In winter, the human body, cased in sheepskins, becomes charged so strongly with electricity, that, on touching a conducting object, it gives off large sparks, with a shock felt through the joints of the fingers.

"The snow line in the central and northern parts of West Nari attains an extreme height of nearly 20,000 feet, and is about 1,000 feet lower on the northern sides of the mountains than on the southern—the reverse of what it is on the southern or Indian Himalaya, where also it lies 2,000 feet lower."—(Journal Royal Geog. Society, vol. 22, Sir R. J. Murchison's address.)

Captain H. Strachey found that the country of Western Thibet, to the north of the snowy Himalaya, is no plain nor plateau, but presents for seventy miles a succession of mountains, which, though ranging from 19,000 to 20,000 feet in height, with flat narrow valleys between, are wholly destitute of snow. And in volume 23, page 65 to 68, rain or snow rarely occurs in the day time, but almost always in the latter part of the night.

The climate of Ladak is extremely dry; on an average of two years there were 31 measurable falls of snow in the year, besides 18 falls of snow on the mountain tops out of reach, and four showers of rain too scanty to be measured. The snow measured $20\frac{1}{4}$ inches.

The theory says, the reason why it rains or snows chiefly in the night is, that the barometer falls at these great heights during the night in consequence of the contraction of the air over the plain by cold; and the cold produced by the expansion of the air from the fall of the barometer, together with the cold from radiation, produces that thin cloud spoken of elsewhere, from which a little fine snow descends.

In the plateau of Ladak, north of the southern Himalaya, 15,000 feet high, the temperature for the summer is from 60° to 80° —an abnormal heat of more than 30° for that great elevation. On the east side of the Rocky Mountains, in North America, in consequence of the considerable rains and snows on the west side and top, the temperature on the slope, four thousand feet high, is equal to that same latitude of the States bordering on the Atlantic. And even as high as latitude 47° , in the midst of mountains capped with snow, I am informed by Governor Stevens, of Washington Territory, that a basin or valley is found where it scarcely snows in the winter, and the cattle support themselves on the grass of the fields, without any provender being laid up for them by the Indians who dwell there. I suppose many such places must exist, or the buffaloes would all die in the winter.

So on the east side of the Doferfield mountains in Norway, near the mountains, on the west side of which there is much rain and snow, the temperature at the arctic circle is as great in the winter as it is 20° south of it on the eastern side of Europe.—(See Dove's Thermal Charts, and many others.)

Even the Ural mountains, far in the interior, running nearly north and south, seem to have a considerable effect on the temperature, as it is warmer in the winter at 60° N. latitude just east of those mountains than it is at 45° just west of them; and as the wind prevails from the west on these mountains, as well as on the mountains of Norway, it is probable that here also considerable rain or snow falls in the winter. It should be remembered, too, that snow is more

efficient in raising the temperature than rain; because the caloric of fluidity is added to the caloric of elasticity, which is more than one-ninth greater.

On each side of the equatorial belt of rain it is abnormally hot, Humboldt says from 10° to 18° Fahrenheit hotter than in the belt of rains in South America; and Becquerel, page 97, says that April is the hottest month in the year, and July the coldest; in some parts of Hindoostan, at Anjarakandy, for instance, between 11° and 12° north, where it rains but little in April and much in July, the mean temperature of April being $85^{\circ}.6$ and of July $78^{\circ}.5$. Nothing could prove more satisfactorily that the temperature of the lower air is diminished by the drops of rain coming down through it from the cold regions above, especially as this phenomenon is observed up to the very base of the Himalaya, six or seven degrees north of the tropic of Cancer. It is worth while to mention here, also, that the barometer stands lower in Hindoostan during the rainy season of summer, than during the dry season of winter on the plains below, though I would infer from theory that it is the reverse at great heights on the Himalaya in consequence of the swelling up of the air in the rain-cloud on the south side of the mountain. I have no facts, however, to prove this last deduction; it is merely theoretical.

195. It is also a deduction from theory that the dew-point will be very low in the morning in the lower parts of the hollows at the foot of the mountains, and for some considerable distance up, whenever there has been a rush of air down them in the night, because the air on these high plateaus will become dryer and dryer as it descends; and as it will follow the rivers in its descent, seeking the lowest places on account of its greater specific gravity, it is probable that it will keep the temperature of those rivers many degrees colder than that of the air, by the great evaporation from their surfaces.

It would hardly have been anticipated, however, from theory, that any of these rivers would become, in any part of their course, colder as they descend; and yet Hooker (vol. ii, page 60) says, "he found the river Zemu, in the summer, increase in temperature from 46° to 48° in going up from its junction with the Thlonok 1,100 feet, and in going 1,100 feet further up, the temperature was 49° , and this occurred both in ascending and descending." This inversion of temperature, however, did not hold all the way down, though "the temperature of the water was constantly much below that of the air;" no doubt for the same reason that the wet bulb of the thermometer stands lower than the dry bulb. In like manner Burns found the water of a river, in the hot desert between the sea of Aral and the Hindoo Koosh, about 60° , when the air was about 100° . The air in this region blows from the north in the summer, and is excessively dry. It would be interesting to trace this north wind to its source; and if it should be found to be some of the air which blows over the Himalaya in the southwest monsoon, which prevails in Hindoostan at the same time, then its extreme dryness would be explained, for *air can never come down from a great height without being very dry when it reaches the surface of the earth.*

In Ladak, just north of the southern Himalaya, Cunningham (page 172, and also in his Journal of Meteorology,) found the wet bulb at noon generally from 20 to 25 degrees below the temperature of the air, at an elevation from ten to fifteen thousand feet. The air in which these observations were made had just passed over the southern Himalaya; for, he says, the dry wind in the day is frequently very strong, nearly always southerly and westerly, summer and winter, though in the night there is frequently northerly and easterly breezes.

I fear the European meteorologists will think me very presumptuous in attempting to explain so many phenomena peculiar to Europe, but they must recollect that I am doing it merely hypothetically, not knowing whether the facts are as I assume them or not. I will venture, then, further to mention one or two more:

196. There is a violent wind called the Bora, which often blows off the Dalmatian mountains from the northeast on the northeastern coast of the Gulf of Venice. This wind is described as rising suddenly and blowing with great violence. Now, if it should be found that there is falling at the same time a heavy rain on the southwestern slopes of the mountains bordering on this coast, the phenomenon would be explained. The mariner, who dreads this Bora, might probably know when to expect the occurrence of this wind by knowing the true cause; for he could see the clouds begin to form on the top and slopes of the mountains many hours before the falling rain would be able to push out the air into the gulf, and yet all this time the wind might be blowing from the gulf towards the mountains.

Again: there is a region north of the head of the Gulf of Venice and south of the Carnic Alps, in which the town of Tolmezzo stands, where great rains take place, with the wind north, and it is stated by writers on the subject that the north wind is the rainy wind in this region. Now, I think it is almost certain that a wind coming over the Alps, especially from the north, could not be a rainy wind on the leeward side; and, therefore, I suggest, with some confidence, that it will be found, by careful examination, that during these great rains the current of air above is flowing from the southward over the under one, coming from the north, and that the rain cloud will be found to commence forming on the southern slope of the mountain, and that after it begins to rain there the lower stratum of air will be pushed back towards the south, and the wind, which is still coming from the south, will be obliged to glance up over the falling rain, and thus the cloud will be propagated backwards from the mountain to a distance which the theory at present is not able to predict.

If the reader will imagine, for the sake of illustration, that the mountain were to move towards the south, side foremost, he will be able to perceive that the rain on the southern slope, and, of course, the wind outwards from the base, would continue, indefinitely, as long as sufficient vapor should be found in the air ascending the slope.

The velocity of the motion of the mountain, however, must be neither too great nor too small, but just so that the drops of rain which are formed at a great height may have time to fall on the southern slope of the mountain. The mountain must also be of the proper height. If it is too high, the air cannot find its way over the top of the mountain; and if it is too low, it will not cause cloud to form on rising up the slope.

Nor is this illustration vain; for it is exactly the way that violent squalls are formed at sea or in the level plains on land, except that the general current of the air behind the squall is substituted instead of the mountain. It is that which gives motion to the squall along the surface of the earth, pushing forward the cold, heavy air through which the rain is falling, whilst this cold, heavy air acts as the slope of the mountain, up which the air ascends to form cloud, by the cold of expansion from diminished pressure, and thus to continue the rain.

According to this theory of squalls produced by falling rain, they ought, in all latitudes, to move in the direction of the general current of the air, though on their approach, especially when they are violent, the air at the surface of the earth ought to blow in towards the squall

cloud as it advances, and then the wind ought suddenly to change below, coming out from the falling rain, while it is still blowing towards the cloud some hundred feet above. The most violent part of the squall ought to be about the beginning of the violent rain, and then the wind ought to die away near the middle of the shower; hence the sailor's maxim, "*the rain kills the wind.*" After the middle of the shower passes, not unfrequently there will be a gentle breeze in the opposite direction—that is, setting out from the centre of the falling rain; but this will be of short duration, for the general wind which carries the squall cloud along will soon prevail. In the latitude of Washington city and Philadelphia, where I lived for many years, these squalls always come from the westward or a little north of west. At Buenos Ayres the pamperos come from the south of west, and at Sierra Leone, on the west coast of Africa, the squalls, called tornadoes, come from the east, in all cases, with a gentle wind meeting them. The theory, also, would indicate that during the great rains that take place north of the head of the Gulf of Venice, and south of the Carnic Alps, there would be felt on the north slope of these Alps a very hot, dry wind, such as the sirocco is described to be.

So the same kind of hot wind ought to have been felt on the north of the Apennines, north of Genoa, on the 25th of October, 1822, on which day, M. Pouillet says, it rained thirty inches in twenty-four hours. And the same phenomenon ought to have occurred north of Joyeuse, on the 9th of October, 1827, when, according to the same authority, it rained thirty-one inches in twenty-two hours! But I have not found in the books any notice of a sirocco on any of these days.

197. There is another wind in the lower valley of the Rhone, called the *Mistral*, which Becquerel (page 323) says is a cold, dry wind, very formidable, coming from the southeast; whilst Lartigue (page 54) says it is from the northwest and north.

Now, on condition that Lartigue is correct, I would suggest the propriety of tracing back this wind to its origin, and then, perhaps, it will be found that it is produced by great rains on the slopes of the mountains facing the valley of the Rhone on the north, that is, the Alps on one side and the Sevennes on the other. If it is a cold, dry wind coming from the southeast, I cannot suggest for it even an hypothetical cause.

If the Sevennes mountains are not very lofty, the wind which produces the rain on the southeastern side may come from the westward, but if they are so lofty that all the rain must fall on the windward side, then must the wind producing the rain come from the southward or eastward, and, of course, must blow over the surface wind, called the mistral, in an opposite direction.

198. There is another peculiar wind called the *Kamsin*, very hot, and very dry, which blows in Egypt from the southwest, never occurring except near the vernal equinox; it comes with clouds of dust so dense as entirely to obscure the sun, and sometimes shows a temperature of 122° Fahrenheit. This high temperature is, no doubt, partly caused by the sand taken up from the hot plains of the desert which borders on Egypt mingling with the wind.

This wind is produced by the approach of the belt of high barometer from the south. During the winter this belt travels with the sun towards the south, and at mid-winter is probably near the tropic of Cancer, and causes the wind to blow from the southward all winter in Egypt; but the country just south and southwest of Egypt does not become intensely hot till near the vernal equinox, and therefore the southern wind in winter is not very hot. As soon, however, as the

border of the belt of high barometer from which the winds blow on each side comes into the vicinity of Egypt, the wind then having but a short distance to go to reach Egypt, even from the middle of the belt, it can be prevented from rising into the upper air, hot as it is, until it passes out beyond the northern part of the belt, where the air is still coming down, as it must do in the whole extent of the belt. That the belt is really in this situation at this time is proved by the fact that up to this time, during the whole winter, the wind is south, and immediately after this time the wind changes to the north and continues from that quarter all summer. This is truly a wind of propulsion from the belt of high barometer, and does not owe any part of its force to aspiration, for there is no region of rain at that time in the north, and, therefore, it is immediately lost in passing over Egypt, ascending no doubt above the surface of the earth as soon as it passes out beyond the northern borders of the belt of high barometer, as abnormally hot air always does.

It is true, this explanation requires that a similar wind should occur near the autumnal equinox, as the belt of high barometer travels south. The books, so far as I know, say nothing of its occurrence at this season, and if it does not occur then this explanation is defective. I can well conceive, however, that the very sudden heat at the vernal equinox would be much more noticed than the more moderate increase at the autumnal, produced by similar winds, and therefore not mentioned. This is rendered probable, as in McCulloch's Geographical Dictionary it is said, in the article on Africa: "In Algiers a north and east wind prevails in the summer without rain, and in August and September sometimes the Kamsin prevails for four or five days at a time, with a temperature as high as 110° , and rarely occurs at any other time. About the equinoxes violent southwest winds occur, and northwest winds are common from November till April, with frequent rains."

199. There is one more wind, which is spoken of in the books as remarkable, called the Harmatan, an extremely dry, but not very hot northeast wind, on the western coast of Africa north of the equator, reaching even down into the region of the rains of the summer. This wind occurs at intervals, only in the winter, when the belt of high barometer is right over the great Sahara.

Neither of these winds is dry merely because it blows over the sandy desert, but because it comes from the descending air of the belt of high barometer. It is true, if these winds on coming down had met with a moist surface to blow over, they would not have to go far before they would become charged with moisture, but there is nothing in the nature of sandy deserts to attract the moisture which the air may have in it, when it blows over them. Indeed, the very fact of remaining dry is a proof that these sands have not absorbed the vapor from the air. The harmatan is nothing but a prolongation of the northeast trade wind into the southwest monsoon of the summer.

The harmatan is undoubtedly a very dry wind, because the belt of high barometer, from which this wind takes its rise, is exactly over the great desert of Sahara, and the air on coming down in the belt finds no moisture to evaporate; but the state of things is entirely changed in the summer, for then the belt of high barometer is removed to the north to near forty degrees of north latitude, producing the etesian winds, which blow entirely across the Mediterranean, and reach the African desert; and except when they cross high mountains, they are charged with much vapor, and retain it until they reach the region of rain about latitude fifteen north.

200. A satisfactory proof of this appears from the fact that whenever mountains are found in

the midst of the desert, abundance of rain is also found. The manner in which mountains produce rain, not by the "cold of their tops," is abundantly explained elsewhere. The same phenomenon occurs in the central parts of South America. Whenever mountains are found in the midst of wide extended plains, *there*, even in the dry season, there is abundance of rain. Such is the case, I believe, in every part of the world, except in very high latitudes, near the poles of greatest cold, where the air is always descending, and therefore always nearly destitute of vapor. I have been told by mariners that it frequently rains every day for weeks at St. Helena, when at the same time there is no rain, and hardly a cloud, for many hundred miles around. So in the dry season, when there is no rain in the adjacent seas and low islands, there is rain every day on the Island of Jamaica, which has lofty mountains.

Where the mountain shoots up in a narrow peak, the cloud producing rain may be prevented by the trade winds from reaching the top of the peak, in such manner that the top of the peak may be seen from a distance above the cloud, which may be pouring down rain on the slope and at the base of the mountain below, and this is said to occur daily at Owyhee, when not a cloud is to be seen in any other part of the sky, and where the rain does not even reach the coast.— (See note 70.)

Hopkins, p. 89, quoting from Malte Brun, says: "The South Sea islands, notwithstanding their small circumference, in this manner, as in a sea breeze during the day time, attract the general east wind, which is thus made to embrace them, as it were, on every side, and to blow from all points of the compass towards the central parts of the island." And it is well known that wherever rains take place in the trade winds there are squalls from all directions, and of course some of them in opposition to the course of the regular trades.

Captain Wilkes, in his Theory of the Winds, p. 72, says: "Our route from Callao to Tahiti, through the Paumotu group, lay between the parallels of 12° and $18^{\circ} 30''$ south latitude. Within these parallels I hoped to have been favored with a strong trade wind; but the winds at this season of the year (July) on the parallel of 18° cannot well be so termed, although generally prevailing from the eastward. The effect of a southwest wind is evident by the interruptions and the long swell from that quarter. The sky was unattended with the usual light clouds that are met with in the trade winds; instead of this, we had the *scud* flying at times rapidly from the southwest."

"During the winter season (from March to September) the trade winds are by no means regular among these islands; they seldom extend so far to the south, and are very often prevalent from the southwest. The weather is frequently very unpleasant, inclining to calms and light winds, with an occasional squall. It is, however, the fine season, for in summer gales from the west not unfrequently occur, blowing very heavy, with rain, and interrupting the course of the trades, often causing a failure to obtain the usual observations for latitude."

I was perplexed to understand the expression above, "we had *scud* flying rapidly at times from the southwest," before the southwest wind commenced, with only "a long swell from that quarter;" but on turning to Captain Wilkes' introduction to meteorology, I find the words "*upper stratum of clouds*" used instead of *scud*. He says the wind afterwards could not be termed the trade wind; though mostly from the eastward, it frequently veered to the southwest, from which quarter the *upper stratum of clouds* was passing rapidly.

It had been cloudy for several days, with a rise of the barometer the tenth of an inch, and

"the clouds above continued to come from the southwest till his arrival off Clermont de Tonnerre, the most eastern island of the Paumotu group."

All the phenomena are, with this view of the subject, capable of easy explanation. The great rains taking place over the Paumotu group caused the air to blow inwards, on all sides below, towards the region of the rain, which, rising over those islands, would receive the latent caloric liberated by the condensing vapor, and then spread outwards above in the region of the top of the cloud, carrying some of the cloud with it, overlapping the air below, and causing the barometer to rise in an annulus all round the region of rain; and on approaching this annulus on the outside of it, the wind would be from the westward, with a rising barometer, and when the region of rain was reached, as it was in the group, the barometer would fall, and such was the case.

201. Captain Wilkes found that the temperature constantly increased, and the barometer constantly fell on approaching the central parts of the great Pacific, no doubt caused in part by the great quantity of latent caloric evolved by the condensation of the vapor in the formation of clouds over these islands. Where he says, (p. 27, Introduction,) there is a great deal of bad weather throughout the year, and in the summer of that hemisphere it is subjected to violent hurricanes. In one which passed over the Samoan group on the 17th December, 1840, the thermometer, at 6 a. m., rose to 88° ; that is eight degrees above its mean standing. As this rise was so early in the morning, it was altogether unconnected with the immediate effect of the sun's rays, and no doubt was produced by radiation of caloric from the overlapping of the air above from the central region of the storm containing the caloric liberated from the vapor just condensed into cloud. Or, perhaps, some of the air containing the latent caloric might, in the turmoil, find its way to the surface of the earth, mingled with the in-blowing air. It is very common, in great hurricanes, for very warm puffs of air to alternate with very cold ones; the cold ones being chilled by the immense floods of rain coming down in particular parts, and the warm ones, perhaps, coming down behind those descending masses of rain; if not so, at least they will be the air intervening between the masses chilled by the rain. The great contrast which these two would afford might, perhaps, be sufficient to induce the observers to characterize them as very cold and very warm puffs. If the temperature of the warm puffs had been marked by the thermometer, it would be known to a certainty whether any of the air had descended from above. In a tornado which passed through the State of Ohio many years ago, it was said, though I cannot vouch for the truth of the statement, that in some places in the vicinity of its path the air was so hot that it scorched vegetation. It is difficult to understand how much hot air could descend from a great height contrary to its natural buoyancy; and, besides, if it were to descend, with its abnormal heat, it would never exceed sixty degrees, even if it should come from the very top of the cloud, and this additional heat would hardly be sufficient to scorch vegetation during the momentary duration of its contact with the surface of the earth, even with the addition of its excessive dryness.

Colonel Reid, p. 93, says: "When the intermitting gusts were strongest, they felt alternately hot and cold. This was in the hurricane off Madras of the 22d May, 1843." The same has been noticed in other hurricanes.

These islands, then, which are situated just within the southern border of the torrid zone, by inducing up-moving currents of air, and of course rain, are the cause of the interruption of the

southeastern trades in this part of the Pacific ; and as there are groups of islands west of these all the way to New Guinea, the same irregularities occur in the trade winds, especially in the summer season, of that hemisphere. West of New Guinea and New Holland is the Indian ocean, reaching to Africa, six thousand miles, uninterrupted with islands almost the whole way ; and here, from ten degrees south to the equator, are the regular monsoons, northwest in the summer of that hemisphere and southeast in the winter, the last being only an extension of the southeast trade.

202. I have said before that the theory here developed is diametrically opposite to the prevailing belief that "the great arid deserts draw in the air on all sides towards their centres of greatest heat, where it ascends and spreads out above." This northwest monsoon of the Indian ocean furnishes one proof, among many others, of the incorrectness of this belief. This monsoon passes east of the northern part of Australia ; and on the northeast border of that great heated island in the summer of that hemisphere, when the sun passes perpendicularly over the central parts of that island every day, the northwest monsoon continues to blow from the northwest, just at right angles to the central part of the island, whereas the theory requires that the wind should blow there from the northeast and not from the northwest. A little further east the winds become irregular, but prevail from the west during the summer there.—(See chart of the winds in volume 6th of *Ann. Hydrographiques*.) And by examining the same chart at the western end of these monsoons on the coast of Africa, it will be seen not only that these northwest monsoons blow away from the great heated regions of Africa, but, more striking still, it will appear that the southwest monsoon, which blows during the summer of the northern hemisphere, blows on the coast of Africa at right angles with the heated region of Africa until it gets past it, and then blows directly away from Africa to the comparatively cool plains of Hindoostan, leaving the Great Sahara and the excessively heated plains of Arabia right in the rear.

Nor does the air stop on these plains ; but swelling up $\frac{48}{480}$ of its whole height above its normal state, from receiving the caloric liberated by the condensing vapor, it rushes over the tops of the Himalayas with fearful violence, and with a velocity vastly greater than it has on the plain below ; just as water rushing over a dam has a much greater velocity than it has in the body of water before it reaches the dam. (Page 149.) So, if we examine how the wind blows on the west coast of Africa, we find that west of the rains the wind blows on the coast from the west, or southwest or northwest, during the whole of the rainy season, whilst near the west end of the Great Sahara no such winds appear.

Annales Hydrographique, vol. I, p. 123.—On the west coast of Africa, about 10° and 11° north, out at sea, the wind blows during the rainy season from the southwest, the west, or the northwest ; sometimes very strong, and occasionally in squalls.

At page 123 of *Annales Hydrographique*, vol I, it is said that on the west coast of Africa, at about 10° or 11° north latitude, they have land and sea breezes during the dry season ; but in the rainy season the breeze blows constantly from the southwest, west, or northwest. It is often very strong, and sometimes degenerates into squalls. The rain is almost continual, and falls with a remarkable abundance, especially in July and August.

The tornadoes which occur in May and June cease during July and September, and occur again from the middle of September till the end of October. It is rare, however, to have one

of them every day. It continues, however, to rain constantly on the mountains of Soumba and Kakulima, and on the highlands of Cape Verga, and does not entirely cease till in November.

A very striking example of this is given by Allen and Thomson's Expedition to the Niger, vol. I, page 73. They are describing a tornado (squall) which occurred on the coast of Africa on the morning of the 23d of June, in latitude 13° north, longitude 18° west. They say: "There generally appears at first a tumultuous assemblage of clouds in all parts of the heavens; these gradually—as if by concert—hurry towards the east, where they assume their stations, forming, by degrees, a long, low arch, extending about six points of the compass. In proportion as the lower edge of this becomes defined and increases in intensity of darkness, so may the near approach of the tornado (squall from the east) be expected." And then they go on to describe the sudden and violent wind and rain from the east, which commence together. The reader will recollect that this is in the region of the trade winds, and that the wind blows from the west on this coast only during the rainy season in the interior. And this is the reason, too, why the squall travels towards the west—the direction which, according to theory, the upper current of the air must have in this locality, especially while there are great rains not far off in the east. Hopkins says, page 41: "There is not even a sea breeze on the western coast of the Great Sahara," over the middle of which the sun passes perpendicularly every day during this rainy season further south.

And if we examine how the wind blows at the western end of the Great Sahara, where, from the theory in question, it ought to be from the northwest, we find that both at the Canary Isles and at Madeira the wind is largely prevalent from the northeast during the summer, and more or less southwest during the winter; in both cases nearly at right angles to the Great Sahara; and also we find that the belt of high barometer passes these islands both in the spring and in the autumn just at the time the wind is about to change to northeast in the spring, and to southwest in the autumn. What is worthy of particular notice in this change is that when the middle of the belt of high barometer passes the Canaries in the spring, and is between them and Madeira, the wind changes northeast at the Canaries, whilst it still continues southwest at Madeira; and when it gets north of Madeira, and has not yet reached Spain, the wind changes northeast at Maderia, whilst it is still southwest in Spain. Phenomena exactly similar take place in South America from latitude 25° to 40° south, as the belt of high barometer moves backwards and forwards with the change of seasons. And the same is true of California, of South Africa, and of Australia. Irregularities, and even interruptions, in the belt of high barometer will, of course, take place where the equatorial belt of rain is interrupted or abnormally removed by abnormal extensions of monsoons.

203. The reader will have but little difficulty in forming a distinct idea of the nature of winds in general, if he will keep constantly in his mind the grand principle on which they all immediately depend, and that is, *they always blow from the region of high barometer towards the region of low barometer*, modified in direction by the revolution of the earth on her axis, as before explained. This principle applies to the currents above as well as to the winds below. They blow from the region of high barometer to the region of low, on the same horizontal level. For example, at the height of five miles, at the meeting of the trade winds near the equator, the barometer must necessarily stand higher than one at latitude 30° north or south, at the same height of five miles, because the air at the equator is swelled up to a great height beyond that at latitude

30°, by the heat liberated there from the constantly condensing vapor, and therefore it will run out above both ways towards the tropics, overlapping the air which runs in below.

It was explained before why this air comes down to the surface of the earth at about latitude 30°, and why it should bring a very low dew-point with it, and why there should be a belt of high barometer there, north and south of the belt of equatorial rains, wherever this belt was continuous.

204. Lieutenant Maury, in his *Physical Geography of the Sea*, has given a very graphic description of the phenomena in question. He says: "The belt of equatorial calms is often several hundred miles across, seldom less than sixty; whereas the depth of the volume of air that the trade winds pour into it is only about three miles, for that is supposed to be the height to which the trade winds extend."

"Thus," he says, "we have the air passing into these calms by an opening for the northeast trade winds on the northeast, and another on the south from the southeast trades, having a cross section of three miles vertically for each opening. It then escapes by an opening upward, the cross section of which is sixty or one hundred, or even three hundred miles. A very slow motion upwards there will carry off the air in that direction as fast as the two systems of trade winds, with their motion of twenty miles an hour, can pour it in." And, at page 113, he says: "I am not unaware of the theory, or of the weight attached to it, which requires precipitation to take place in the upper regions of the atmosphere, on account of the cold there, irrespective of the proximity to mountain tops and snow-clad hills. But the facts and conditions developed by this system of research upon the high seas are, in many respects, irreconcilable with that theory."

As Lieutenant Maury has done me the honor to allude to my theory in the extracts above, I would respectfully request him to examine what I have said on this subject in another part of this report, and I doubt not that he will find reason to change his views on this point; and if so, it will, of course, modify his whole theory, and he has reputation enough to acknowledge it, without either mortification or diminution of fame. Nor do I doubt, from his love of truth, that he will gladly abandon the unintelligible paradox of supposing that the whole of the southeast trade wind passes to the north, and the whole of the northeast trade wind passes to the south, each permeating the other as they pass through the region of the calms, provided he anywhere finds a satisfactory explanation of all the phenomena.

So, if he finds that, in fact, the winds, in very high latitudes within the polar circles, actually blow in general from the poles below towards the belts of low barometer near the polar circles in the Atlantic and Pacific in the north, and all round the globe in the south, he will abandon the speculation that the air round the poles rises up, contrary to its greater specific gravity, and spreads out above in all directions over the air below which flows towards the poles.

To the evidences given in the last report, reproduced in this, that the winds do actually blow on both sides of the belts of low barometer and constant precipitation near latitude 60°, both from the frigid and temperate zones, I will add a few more here which, I think, are quite conclusive on the subject. Besides the direct evidence furnished in the following extracts, I would ask the reader if there is not some reason to believe that the belt of ice was kept in the belt of rains, and snows, and low barometer, by winds blowing towards it on both sides?

205. "I would here note the fact, which has been proved in the recent experience of the

commanders of our South Sea sealing expeditions on the passage round this noted cape (Horn) into the South Pacific, since the rediscovery of New South Shetlands, and of the continent of Palmer's Land to the south of them, that a ship, desirous to make the passage the most favorable and advantageous in every point of view, should, on leaving Cape St. John's, stand boldly off to the south until she arrives up to the latitude of 63° south, keeping constantly with the prevailing southwesterly gales on her starboard tack; by so doing, should these gales flat her off to the eastward so as to fall in with the South Shetland islands while endeavoring to obtain the above latitude, no disadvantage will occur, for it will not be long after getting sight of these islands before the wind will be round from the southeastward, when, by keeping between the latitudes of 63° and 65° south, she will have easterly winds, so as to be able to run up her latitude in a short time. It is well ascertained that the west and southwest gales on the cape side and in the stream (effected as is supposed by the mountains of Palmer's Land and the islands) blow at the same time from the south and southeast above the latitude of 63° south."—(Fanning's Voyages Round the World, page 104.)

And at page 473 he says: "The report of all (within the author's knowledge) that have passed beyond the 68th degree of south latitude is, that above this degree the sea was found to be mainly clear of ice, and the climate becoming more mild with prevailing winds from the southward." And in the Jour. Roy. Geog. Soc., vol. 2, p. 111, it is said: "In very high latitudes south, when actually, as it were, within the ice, the winds were almost uniformly from the south round by southeast to E.N.E.; outside the ice to the north, however, the winds were constantly westerly."

Captain B. Morrell says, page 67, "I have several times passed within the antarctic on different meridians, and have uniformly found the temperature, both of the air and water, to become more and more mild the further I advanced beyond the sixty-fifth south latitude. While north of this latitude, say between sixty and sixty-five south, we frequently had great difficulty in finding a passage for the vessel between the immense and almost innumerable ice islands, some of which were from one to two miles in circumference and more than five hundred feet high. *We found much less ice and much finer weather south of latitude sixty-seven than we did between sixty-seven and sixty, and in passing from one of these latitudes to the other it rained, or snowed, or hailed, more or less every day for sixty-six days.*"

"The ice islands, on being detached from the original place of formation by some violent storm, are conveyed to the westward by the southeast winds, which are prevalent here, and are found, the first season after their separation, about seventy miles north of the barrier of ice attached to the antarctic continent. The movement of the ice along the coast is entirely to the westward, and all the ice islands and bergs were found in that direction, while the eastern portion was comparatively free from it."—(United States Exploring Expedition, vol. 2, pages 332, 334.)

"The winds which prevail from the south to the southeast occasionally bring clear weather, interrupted by flurries of snow. The north wind is light, and brings thick fogs, with a rise of temperature. Extremes of weather are experienced in rapid succession, and it is truly a fickle climate."—(Same.)

I wish to call the attention of the reader to the fact that the weather was milder and more pleasant on the polar side of the belt of rains and snows than in the belt itself. It seems

impossible to mistake the cause of this mildness. It is the radiation of the abnormal heat of the upper air, thrust out from the top of the cloud, with much of the latent caloric in it, liberated from the condensed vapor which formed the cloud. It was shown before that, according to theory, this upper current from the belt of rains and snows runs towards the pole, radiating off its abnormal heat, and when that is done, being entirely dry, and specifically heavier than moist air, it sinks down to the surface of the sea and blows back again to the belt of precipitation below.

I request the reader also to notice that the motion of the ice in the band of rains and snows and low barometer was from the east towards the west, which, I think, affords a presumption that the southeast wind, spoken of as being prevalent on the polar side of the belt, while the observer was there, is really the direction of the wind generally throughout the year. It follows then, if this is the case, that the barometer must stand higher near the pole, from which the wind blows, than it does in the belt of rains near latitude 60° , to which the wind blows. And there is abundant evidence to prove that on the tropical side of this belt the prevalent wind is largely from the northwest, in the southern hemisphere, and from the southwest in the northern hemisphere.

Nor are facts wanting to favor this deduction from theory; and none that I have seen are against it. To those that have been mentioned before, I will merely add here, that Captain Wilkes found the barometer lowest between 63° and 60° south. At a mean in these latitudes it was about 29.00 inches. He spent one day in about 67° south, and the barometer on that day was never below 29.20, and for several days, between 66° and 67° , the barometer stood above 29.00; whereas, between 63° and 64° on one day, the mean of the barometer was 28.638; and the wind was constantly from the southward in latitude 66° and 67° near the icy barrier; whereas, in latitude 59° and 60° it prevailed from the northward, and much rain and snow fell in the belt between those latitudes, towards which the wind blew on both sides. Indeed, this antarctic belt of rain and low barometer seems to be continuous all round the globe, which is not the case with any other belt of rains, not even the equatorial.

206. The arctic belt of low barometer and rain is interrupted, or at least much modified, by the great continents of Asia and Europe on one hand, and North America on the other. But it is well defined in the north Atlantic, as was shown before.—(98.)

The reader will please to examine that article in this connexion. As to the northern part of the Pacific, "on the eastern coast of Kamtschatka, the prevailing winds are west from the end of September till May, while on the opposite coast of America, at New Archangel, latitude $57^{\circ} 3'$, the prevailing winds at the same time are from the east, accompanied with much rain and snow. In the island Ounalaschka, latitude $53^{\circ} 52'$, between the coasts of Asia and America, the wind is south 170 days in the year, southwest 106 days, and south-southwest 41 days," (Ann. Hydrographiques, vol. 6, page 333;) and Beechey, on passing north of Behring's Straits, found the winds prevail from the northward, and the barometer stood more than a quarter of an inch higher than it was south of those straits. Now, as the wind prevailed from the northward in the highest latitudes, 66° , 67° , reached by Captain Beechey, it is certain that the barometer was still higher further north; and if the air was both colder and dryer there than in the belt of low barometer, it would be specifically heavier, and therefore descend and blow outwards from the region of the highest barometer, as explained at large before.

It is certain, also, from theory, that this cold dry air would blow out further from the pole of greatest cold during the winter, and wherever the belt of low barometer and snows is well defined, even if it should be as low as 45° north latitude, on land or sea, it is highly probable that just north of the belt of great snows the weather will be much milder than it is in the belt of snows and low barometer, though that belt is in a lower latitude.

207. It was said before that the cold dry air will frequently push itself out from the polar regions in the shape of a wedge, while the air above is running in towards the pole. Now as this upper air must slope upwards as it advances towards the pole, where the cold stratum of air below is constantly increasing in thickness, much of the vapor condensed in the belt of deposition may take place where there is a northerly wind at the surface of the earth. Such a wind, pushed out from high latitudes, when it reaches much lower ones, will be northeast in the northern hemisphere, and southeast in the southern. When such a storm as this takes place, the barometer is likely to fall to the lowest point before the snow comes on, and the wind will be likely to blow with violence, from the northward in the northern hemisphere, and from the southward in the southern, with a rising barometer. Many such storms occur in the vicinity of Cape Horn, and some approach that character in the United States.

As a specimen of the manner in which this kind of storm is got up sometimes in the United States, I extract the following account of one from the *Philosophy of Storms*, page 179 :

“The gale commenced at Springfield, Ohio, about $10\frac{1}{2}$ P. M. of the 22d January, 1839; it reached Lancaster, Pennsylvania, on the morning of the 23d, at ten minutes past seven, Reading about seven, and Philadelphia about 40 minutes past eight.

“This gale was preceded by no southeast wind, at least at Philadelphia and Lancaster, Pennsylvania, and Springfield, Ohio, but it was everywhere in Pennsylvania accompanied by a furious snow storm, commencing just before the northwest wind set in. The northwest wind was very violent, probably about forty or fifty miles an hour, which seems to be about the velocity with which the storm moved while passing from Springfield, Ohio, to Philadelphia.

The central line of this storm, also, was not directed exactly north and south, but east of north and west of south. It passed Stroudsburg in the northeast corner of Pennsylvania, ten minutes before it reached Lancaster, about a hundred miles southwest of Stroudsburg, and it was about an hour later in reaching Snow Hill in the southeast corner of Maryland, about 250 miles south by west of Stroudsburg.

Here was a most remarkable vein of snow several hundred miles long, from north by east to south by west, and only about twenty miles wide, moving side foremost, and snowing only a very short time at any one place—half an hour at Philadelphia and Stroudsburg, and still less time at Snow Hill and Lancaster.

This vein of snow was preceded by a fall of the barometer, and succeeded by a very sudden rise of about half an inch in a few hours, and of three-fourths in twenty-four hours.

It was also succeeded by a sudden fall of the thermometer of 20° , and in a few hours of 30° .

The difference of barometric pressure on the east and west of the vein of snow, caused no doubt by the difference of temperature, was sufficient to produce the violent westerly wind on the west side of the vein of snow, and as the air in the front of the vein was calm or nearly calm until within a few minutes before the northwesterly wind commenced with violence, it is manifest that the air east of the vein, on the approach of the northwesterly gale, (which, indeed,

was most violent in five minutes after it commenced,) must have ascended; and when it reached a certain height it would form cloud, which would give out latent caloric both of elasticity and fluidity, which would expand the air in the cloud, after allowing for the condensation of the vapor, nearly eight thousand cubic feet for every cubic foot of water thus formed and congealed into snow.

This great expansion there would cause the air to swell up and roll over towards the northwest above, diminishing the weight of the barometric column on the east of the vein and increasing it on the western side; and its violence would be increased or diminished as it passed over the country with a higher or lower dew-point. Moreover, the particles of snow would be carried up to a great height by the ascending air on the east side of the central line, and thus become excessively cold, and in falling down through the air on the west side would diminish its temperature very much, and cause the barometer to rise on the west side, both by their own weight and by the increased weight of the air by cold.

208. There is another very instructive phenomenon connected with this storm, or rather squall. The excessively cold air which followed this very narrow vein of snow covered the whole country east of the lakes, and on the night of the 24th, twenty-four hours after the squall, a storm commenced on the lakes, and on the morning of the 25th the thermometer had risen from -17° to $+27^{\circ}$, that is 44° at St. Lawrence in the northern part of the State of New York, just northeast of the incipient storm, while it had not begun to rise in the southeastern parts of Pennsylvania and the southeastern parts of New York, for at Clinton Academy it was $+10^{\circ}$, and at Mount Pleasant $+8^{\circ}$. In the mean time the wind began to blow towards the approaching storm from the southeast, commencing in the northwestern parts of New York before it commenced at the southeastern parts, showing that this was truly a wind of aspiration.

Now, I think, that there can be no doubt that this sudden increase of temperature in the night, in the vicinity of an incipient storm, while for many hours the temperature continued very low to the southeast and south of the locality of the sudden and great rise of temperature, was due to the radiation of the abnormally heated air above, containing the latent caloric of the vapor just condensed, and thrust outwards from the centre of the incipient storm, especially over the regions to the east. This storm turned out to be a most violent one, and on the next day, the 26th, it covered almost the whole of the eastern States, blowing violently from the eastward along the coast, and violently from the westward in the State of New York towards the central region of the storm and low barometer.—(Philosophy of Storms, page 184.)

It would be highly interesting to know where the northwest wind in this and like storms originates. There are two ways in which it might originate, and theory is not able to determine positively which is the true one. One is that it comes from the downward motion of the air in the frigid zone, the other from an annulus of high barometer south of a great storm which may be raging near the arctic circle. The outspreading of the air above from such a storm would cause a high barometer some fifteen or twenty degrees to the south of it, and thus cause the air to blow from the northwest, and then from the north and northeast, provided the storm at the arctic circle moves towards the eastward.

Theory, however, seems to indicate that if the wind continues to blow for many days in succession from the north with a high barometer that it is a polar wind; but of this the theory cannot be certain; for if the storm at the polar circle, or near it, should be stationary, or of

great length east and west, the northerly wind south of its annulus of high barometer would continue. Observations made as high as 55° north would decide this point; for if the wind at that parallel should be found blowing from the south at the time of the north wind in latitude forty, it would show that the north wind in the lower parallel was not a polar wind, but was from the annulus of high barometer produced by a storm between that annulus and the pole.

209. The origin of the trade winds is in the belts of high barometer in their outer or tropical borders near latitude 30° at a mean, these belts corresponding to the annulus on all sides of great storms that pass over the United States from which the strong winds originate which blow in towards the centre of these storms, where the barometer is at a minimum. And *there* is the termination of the winds. So the termination of the trade winds is in the rain belt of the equator; and there is no corollary from my theory more certain than that *the termination of all the winds, in all great and wide extended storms, will be in the region of rain and, of course, never in the centres of arid deserts, however hot they may be.* Even in the torrid zone, wherever the winds change for a time and blow from the west, this west wind terminates in a region of rain. The monsoon in the Indian ocean, which blows from the northwest during the southern summer, terminates in a belt of rains 6,000 miles long. The monsoon of the Arabian sea, which blows from the southwest during our summer, terminates in a great rain on the Himalaya, and, according to the theory, if the Himalaya was removed, the wind would meet it from the northeast, and the monsoon would probably not then pass beyond the Ghauts, 20° further south.

The northern monsoon, which blows into the northern end of the Mozambique channel in the southern summer, terminates there in a great rain, and the southern trade, which blows into the same channel at the same time, terminates there in the same rain; and the ship that is caught in that channel at that season finds the wind dead against her at whichever end of it she tries to escape.

So in the temperate zones, between the latitudes of 30° and 60° , where the prevailing wind is from the west, whenever the wind blows strong from the east for some time, that wind terminates in the region of rain, and originates in the annulus of high barometer which always surrounds the region of rain storms of great magnitude, at more or less distance according to the diameter of the storm.

This deduction from theory is abundantly proved to be correct in the United States by the facts communicated in this report, and in those preceding it, and theory says it must be so in every part of these zones all round the earth, wherever the prevailing wind is from the west.

The reader may perhaps think that the narrow squalls in which the wind blows outward from the falling rain ought to be excepted from the general law of winds terminating in regions of rain. Squalls have been explained at large before as being caused by the impulse and cooling effect of the rain on the air as it descends from a lofty and cool region above. I will only say here that, even in this case, the cloud producing a squall by its down pouring rain is formed by an up-moving current of air, and just before the commencement of a violent squall the wind below blows towards the cloud at the surface of the earth.

I will take the opportunity of mentioning here another kind of squall indicated by the theory, though I have never had the good fortune to see one, and that is one produced by a rapidly forming cloud, before it begins to rain. In this case, if a ship at sea should happen to be near the borders of such a cloud it would experience a strong wind blowing towards the centre of the

cloud. The observer, however, to experience this effect of a rapidly forming cloud, must be very near it; for, at some distance from such a cloud, the air spreads outwards above, all round the cloud, forming an annulus, in which the barometer rises, while it sinks under the middle of the forming cloud in proportion to the increasing perpendicular diameter of the cloud, and on the outside of that annulus the wind will be gentle from the cloud. It is only when there is a very rapid increase of a cloud that this effect will be observed.

210. There is one more phenomenon indicated by theory of an opposite character, which I have had the gratification of seeing sometimes on land, that is, the air blowing outwards from under a cloud without rain. Theory indicates this phenomenon in the following manner: All clouds are either forming or dissolving clouds. As long as there is an up-moving current of air under the base of a cloud, it is a forming cloud, and as soon as a cloud is cut off from the up-moving current which formed it, it begins to dissolve.

The particles of water which form the visible part of the cloud have eight or nine hundred times the specific gravity of the air in which they are condensed, and of course they begin to descend by their own weight as soon as they cease to be supported by an up-moving current of air. In coming down into air below not saturated with vapor, they begin to evaporate, and in evaporating they cool the air and increase its specific gravity, and it, too, begins to descend, and the stratum of air just above follows after with its particles of water, now falling faster in consequence of the motion of the air downwards, and this process goes on accelerating, as more and more particles of cloud evaporate, and finally a current of air moving downwards under the cloud will reach the earth, and of course blow outwards from the dissolving cloud. In short, the process is exactly the reverse of what takes place in an up-moving column of air in which cloud is formed, though the violence of the wind outwards from the cooling effect of the dissolving cloud can never be so great as it is inwards, towards the centre of the forming cloud. Under such a squall or puff of wind the barometer rises a little. Sometimes these puffs of wind occur without any cloud being visible, either because the cloud producing them is entirely dissolved, or because of the instability of equilibrium in the air; but even in the latter case the barometer will rise perceptibly on account of the greater specific gravity of the descending air. It will be observed by the careful observer that these strong puffs of wind, with a rising barometer, are invariably produced by propulsion, and never by aspiration; and that on the leeward side of them there is a calm, or at least a more gentle wind than usual, for the wind that comes down brings with it the horizontal velocity which it had in the upper regions. This is the only way to account for strong insulated puffs of air in the midst of a comparatively still atmosphere; for a portion of air in the midst of a comparatively calm atmosphere cannot commence moving horizontally much faster than the air all around it.

The mariner, as well as the farmer, may always distinguish a forming from a dissolving cloud by its appearance. I mean the cumulus, when the whole size and shape of the cloud can be seen. The forming cloud has all its outline well defined with a flat, dark base, and by watching it carefully it may generally be seen to increase at the top, while the base remains on the same level; but the dissolving cloud has its edges ragged and ill defined, and may generally be seen to decrease in size and its top to become lower.

It is not necessary to say to the reader who examines my theory carefully, that the observer of the forming cloud need not expect to see its base rise further from the surface of the earth on

account of the ascending current of air under it, nor that of the dissolving cloud come down to the surface of the earth, on account of the descending current under it; because, in the first case, the vapor going up with the current constantly begins to condense into cloud at the same elevation by the cold of expansion from diminished pressure; and in the last case, the particles of water forming cloud evaporate by the heat of increased pressure before they reach much below the original base of the cloud.

And yet a late writer thinks he has demolished my theory by a single stroke of his pen in saying that "clouds when forming have no up-moving current of air under them, for he has observed these clouds with care for many years, and they are never carried upwards, but swim along at the same height undisturbed by the wind below."

211. M. Becquerel, in his Meteorology, page 279, after having spoken of oceanic currents produced by winds, says: "We will notice, besides, some movements which are independent of the winds and tides, and which produce sometimes little currents at the surface of the sea, such as M. Humboldt has described them in his voyages to the equinoctial regions."

"When the sea is perfectly calm, there appear at its surface narrow bands, like little rivulets, in which the waters flow with a noise very sensible to the experienced ear of the pilot. On the 15th of June, in latitude $34^{\circ} 36'$ north, we found ourselves in the midst of a great number of these beds of currents; we could take the direction of them with the compass. Some set to the northeast, others to the east-northeast, though the general movement of the ocean continued to be, by observation, to the southeast. It is very common to see a mass of still water traversed by fillets of water, which run in different directions. This phenomenon can be seen daily at the surface of our lakes; but it is more rare to find partial movements impressed by local causes on small portions of water, in the midst of an oceanic river of immense space, running in a constant direction, though with small velocity. In this conflict of currents, as in the oscillation of the waves, our imagination is struck with these movements, which seem to penetrate each other, and with which the ocean is constantly agitated."

It is probable that those numerous ripples which the mariner sees frequently over the otherwise smooth surface of the sea, resembling superficial currents, may be produced, some by up-moving currents of air under forming clouds, and others by down-moving currents under disclosing clouds. Are not fitful breezes produced by the same causes, when they occur without rain?

If these breezes are produced as here suggested, the mariner will be able to distinguish the one from the other by the following characteristics: When the forming cloud is to the leeward near enough to produce disturbance by the up-moving air under its base, the wind will be increased in force without change in direction; but if the forming cloud is to the windward, the force of the wind will be diminished, and *vice versa* with a dissolving cloud. Moreover, there will be a slight fall of temperature in a breeze produced by the downward current of air under the dissolving cloud, though not so great as in the squall produced by rain.

It is probable, also, from theory, that a dissolving cloud, when examined by Leslie's aetheriscope, will be found to be colder than the surrounding air, though it is known that clouds generally show a higher temperature by this beautiful instrument. Humboldt found that a cloud rolling down the side of a mountain in South America was several degrees colder and much dryer than surrounding air.

This last phenomenon is not only unintelligible, but incredible, if it was true, as is generally believed, that air in contact with water always in time becomes charged to saturation with vapor—that is, has its dew-point and temperature of the air the same; but that such is not the fact was shown before.—(41.)

Professor Henry suggested to me that, as the tenacity of the particles of water for each other in very minute globules of water, such as they are in cloud, is greater in proportion to their minuteness, it may require them to be placed in air where the dew-point is many degrees below its temperature before they begin to evaporate at all.

I have known it to rain two hours, and then, in the midst of the rain, the temperature of the air was 60° and the dew-point $46^{\circ}.2$ —that is, $13^{\circ}.8$ below the temperature of the air, (116;) and, in general, I have found the air far from being saturated in time of rain; and when the temperature of the air and the dew-point do approach near each other in time of rain, I have generally found, at least in summer, that it was rather from the lowering of the temperature of the air than from the elevation of the dew-point.

212. Will not this principle also explain the “RED FOG” which Captain Wilkes saw five or six degrees north of the equatorial belt of rains? This fog appeared in the regular trades, with the sky in other respects clear. The barometer was about 30.02 inches, the temperature of the air 78° , and of the water 82° , and degree of moisture .706, which would make the dew-point about 66° , or 12° below the temperature of the air, in which very minute particles of water, according to Professor Henry, would not evaporate.

Although the air was comparatively dry, there is no doubt that this mist was very minute particles of water in the air, for in the evening it was accompanied by a deposition on the surface of bodies exactly similar to dew, except that it appeared on all bodies alike, without any diminution of temperature, with a fresh breeze and even before sunset, and appeared alike on good and bad conductors. This deposition was therefore not dew in the proper sense, as explained by Wells.

Captain Wilkes thinks that these minute particles of water were formed in the air by the mingling of different portions of air at different temperatures according to the Huttonian theory.

According to the theory here developed, the explanation of this phenomenon is easily given. The air in the upper current, when it first left the belt of rain, was abnormally hot, having the caloric in it just liberated from the condensed vapor, and, moreover, was saturated with vapor remaining in it uncondensed; as this air proceeded towards the north it radiated off its abnormal heat, and thus condensed some of the vapor in it, which it could not retain at a lower temperature.

213. Nor is this principle, however unexpected, unimportant in the economy of nature. If the drops of rain coming down through the lower air should raise the dew-point without cooling the air, every rain storm in the summer would leave the lower atmosphere in a more murky, uncomfortable state than it was at the commencement of the rain. Indeed, the whole concatenation of causes in operation in the production of rain is worthy of our highest admiration. For instance, if water was not evaporable, we should have no vapor to make clouds and rain of. If air was not expansible by heat, we should have no up-moving currents in it to commence the formation of cloud; indeed, we should have no winds at all. If vapor contained no latent caloric, the up-moving columns could not exist as they do now. If air did not cool by expan-

sion from diminished pressure as it ascends, it would not condense the vapor in up-moving columns as it does; and if vapor cooled by expansion in going up as fast as air, it would not condense into cloud as it does now. If air did not radiate into space, the abnormal heat which it receives in the region of the clouds from the condensing vapor, up-moving columns would not go high enough to form clouds, for they would not penetrate and rise in air hotter, and therefore lighter, than themselves.

If the upper air radiated away its abnormal heat slower than it does at present, it would be longer between the rain storms, and there would be less rain than there is with the present constitution of things, for up-moving currents of air depend as much on the cold of the upper region as on the heat of the lower. Besides, the distance of the tropical belts of high barometer from the equatorial belt of low barometer and rain depends on the radiating power of the upper air. The more rapidly it radiates the sooner it will reach the place where it will begin to sink down from its greater specific gravity, which it will have from its greater dryness as soon as its temperature becomes normal—that is, the same as that of the latitude where it descends.

If vapor permeated air by its own elasticity so as to move from a high to a low dew-point with such velocity as to move from the equator towards the poles even contrary to the wind, then it is true we would not need up-moving currents of air to produce rain, for the vapor would rush up through the air to a lower dew-point five miles high, than it would find by going horizontally from the equator to the pole, and then we should have rain without ceasing, or at least eternal cloud with nearly constant drizzle. The vapor in thus ascending, besides having a much shorter distance to go to find a low dew-point, would have its specific gravity to aid its motion, and a rarer atmosphere to move in as it ascended. The fact that the vapor does not thus ascend is a proof that vapor does not rapidly permeate air. There is one other phenomenon probably due to the cold of descending currents from dissolving cumuli—I say cumuli, for it is they only that produce these cold descending currents.

At the time of the latest frosts in the spring, and the early frosts in autumn, it is known that these frosts are very partial, never or rarely extending over a wide extent of country at first. For, even in the same neighborhood, where the farms are similarly situated, and on the same level, one farmer will have his tender vegetables killed by frost, and his neighbor's will be untouched.

The hypothetical explanation is, that over one of these farms there descended in the evening a cold current of air from a dissolving cumulus, whilst the other was just beyond the boundaries of the cold air, and that the temperature of the night was such that the difference of a few degrees would be sufficient to produce frost in one place and not in the other. I repeat, that many of these explanations are merely hypothetical, and are intended to produce further examination into the causes of these curious phenomena; and if it shall be found that any or all of them depend on other causes than those I have suggested, it will not at all invalidate the general theory here developed. It depends not at all on hypothesis, but on the most remarkable concatenation of facts and principles that was ever brought to bear on any theory since the establishment of the sublime theory of universal gravitation.

214. As to *changeable winds* and *great fluctuations* of the *barometer*, the whole theory teaches that they are due to the evolution of latent caloric in the formation of cloud.

I have shown that this cause alone, under favorable circumstances, can diminish the weight

of the barometric column one tenth of the whole under the centre of a hurricane cloud, and such a diminution of weight is able to produce all the violence experienced in that fearful meteor.

The sun sends into the atmosphere nearly equal quantities of heat in each of two successive days, and therefore the sudden great changes of weight in the barometric column cannot depend on the direct influence of his rays. But when a great ocean of vapor is condensed in a limited portion of the atmosphere during a storm of rain, the whole quantity of caloric absorbed by that vapor from the heat sent down from the sun for many days is discharged into the air in a very short time, causing the air to expand in the region of the cloud, and to spread outwards above from the centre of condensation, causing the barometer to rise all round the cloud in an annulus, where it sinks downwards by its superior pressure, and dissolves any clouds it may there contain by the heat of increased pressure which they experience in their descent, thus producing, in the case of great and sudden storms, clear weather all round their borders at a distance proportional to the width of the storm.

The barometer will fall much more under the middle of the storm cloud than it will rise in the borders, and the air will run in from all sides below with a force proportional to the difference of the pressures at the centre and the annulus; a velocity of 240 feet a second when the barometer sinks one inch in the centre, in the case of very slender up-moving currents, such as in the tornado, where friction on the surface of the earth may be neglected in the calculation.

This is the theory and this is the deduction which was drawn from the theory before the facts were known. And now, since it is abundantly proved that the facts correspond with the theory, the theory is established, and should be recognized by the highest scientific authorities in the world. Until it is so recognized, the smatterers in the science, and the mere book makers, will continue to copy, one from another, all the old absurdities, such as, that rains are produced by the mingling of masses of saturated air of different temperatures, and that the wind blows in all directions towards the centres of heated arid deserts, without noticing the fact, which is now well established, that from latitude 35° to 60° , on both sides of the equator, the wind blows from the warm region towards the cold—from the belts of high barometer, at latitude 30° , towards the belts of low barometer and rains near latitude 60° .

215. Theory also says that the upper currents of air over these belts of low barometer, near the polar circles, ought to run outwards from the centre, both towards the poles and towards the belts of high barometer near latitude 30° .

This deduction of theory needs confirmation from observation. So far as observations have been made they are favorable to the theory.

It is well known that the ashes thrown into the air by volcanoes penetrate the upper current, and are carried to great distances contrary to the wind below.

A remarkable case of this kind occurred in the summer of 1783 in Iceland. A very full account is given of it by M. Ch. Martins in the *Annuaire Meteorologique* for 1851, page 207, 220, in his learned investigations of *dry fogs*.

This fog appeared at Copenhagen on the 24th May, at the very time when the volcano began to vomit smoke and ashes. It then extended to France, Germany, and Italy, where it was remarked almost everywhere on the 16th and 18th of June, and by the end of the month in Spain, Portugal, and Syria, and at Moscow and Buda. It began generally in the northwest first, and terminated last in the southeast, and continued over the whole country two months,

and all this time the volcano was in action. It reached to a great height in the air, above the highest Alps, and is demonstrated by the author to have been produced by the volcano; and therefore it is highly probable the mean direction of the upper current of the air was from the northwest during these two months all the way from Iceland to Syria, 50° in longitude and 30° in latitude. It is quite natural that it should widen out as it travelled, for we hear of many storms during its march, and it is not a little remarkable that its southern boundary seems to have been at or near the belt of high barometer, which was at its greatest distance from the equator at the time. Beyond this belt this dry fog could not go if the wind below was in its normal direction on the north side of the belt; that is, from the southwest.

In the same volume quoted above, p. 264, the illustrious Quetelet, of Brussels, has given a table of the direction of the currents of the air as shown by the clouds, and also by the vane.

It would be more satisfactory if the upper and lower clouds had been distinguished in this table, for very often the lower clouds march with the wind below when the upper ones move in a different direction; and in the latitude of Washington City and in Philadelphia the upper clouds often are north of west when the lower ones are south of west, as I can testify by many years observation.

According to Quetelet's table, embracing observations from 1833 to 1846, for every 447 observations in which the clouds were moving from some northerly direction, the wind below was northwesterly only 337 times.

In this table I find that the clouds come from the eastward 244 times in 1,000, and I wish to call the attention of M. Quetelet to the fact, that though the lower clouds always come from the eastward in this locality just before the setting in of a great storm, the upper clouds at that time are moving with abnormal velocity from the westward; and I have not found the true cirrus clouds to average hardly once a year from any eastern direction, and when they do come from that direction, it is only when there is a storm of uncommon violence in the east. An ordinary storm has not the power to push the upper rim of the storm cloud backwards against the prevailing current from the westward in that region.

I once saw, during a violent hail storm about thirty miles northeast of my place of observation, Washington city, the upper part of the hail cloud pushed back over my zenith with considerable rapidity, but after reaching within about 40° of the southwest horizon it gradually rose and returned towards the eastward, leaving the whole western sky perfectly clear. I have seen the cirrus coming from the east several times when there was a storm of great violence raging some hundred miles out in the Atlantic; and I think, from my own observations alone, I can safely say that this phenomenon never takes place in this locality under any other circumstances. In other words, it may safely be inferred that whenever the cirrus clouds are seen coming from the eastward, there is a storm of uncommon violence in that direction.

The tables of M. Quetelet, however, at least favor the idea that the upper current comes more frequently than the lower from the northward.

In the same volume, page 357, is given, by M. Bertrand de Dove, a very interesting account of the superior and inferior winds of Puy in France. The table which he gives contains the observations of only two years; but as he distinguished the upper from the lower clouds his observations are very precious in this connexion. In this table the upper current northerly,

that is, from the northward, is to the upper current from the southward, as 2.65 to 1, and the upper current from the westward is to the upper current from the eastward as 5.75 to 1.

M. Dove does not say that all the upper clouds were cirri, nor is it likely that they were. In the United States these clouds are rare in the winter. They are all made out of the top of rain clouds, being the remainder of the cloud after it is done raining. At first, when the cloud is done raining, only the outside rim of the cloud exhibits the hairy form of the cirrus, which may be seen even while the cloud is raining; but if the observer will watch the cumulus forming till it turns to nimbus, he will see the upper part of the cloud protruded outwards, fading off into cirrus; and when the cloud is done raining the whole top will thin out into cirrus, and become thinner and thinner until it disappears—such is my experience; and this cirrus being very lofty, though not so lofty as the top of the most lofty cumulus, is well calculated to show the direction of the upper current, and according to my observation its prevailing direction in the summer is towards a point a little south of east.

In the report of the 23d meeting of the British Association, page 33, Mr. R. Russell says: “Both Mr. Green and Mr. Mason are of opinion, from their æronautic experience, that in whatever direction the wind may blow at the surface of the earth, at 10,000 feet high the current was invariably from some point between north and west. This opinion was no doubt carried too far,” says Mr. Russell, “but it clearly shows the frequency of the northwest wind above the lower currents.”

In the Transactions of the Royal Society of Edinburgh, vol. 19, part 2, page 104, are given the resultant direction of the different currents of air for the years 1843–’46 at Makerstown, latitude $55^{\circ} 34\frac{3}{4}'$, longitude $0^{\circ} 10' 35''$ west.

Surface current west	21° south
Scud current west.....	7° south
Cirrostratus current west.....	2° north
Cirrus current west.....	9° north
Lowest barometer in November about.....	29° 33
Lowest barometer in December about.....	29° 36
Highest barometer in March about.....	29° 74
Greatest rain in autumn.	

Finally on this point: if it is established by observation that the prevailing direction of the wind at the surface of the earth in middle latitudes is from the equator toward the poles, then, independent of all observations of the clouds in the upper regions, we may infer, with absolute certainty, that there is an upper current from the frigid zones towards the tropics.

216. M. Becquerel, in his Meteorology, page 283, says: “It has been ascertained from measurements of the quantity of water discharged by the Seine at the bridge of the Chamber of Deputies, is, by M. Dause’s measurement, one-third of the quantity falling in rain and snow in the basin of the Seine above Paris, and according to M. Mariotte’s, only one-sixth.” So that from four to five-sixths of the whole that falls must be evaporated; for the quantity used by vegetation may be neglected.

It is probable that very little of the water evaporated in the basin of the Seine is poured down there again in rain, for the prevailing westerly winds there carry it off to the east to furnish moisture for more thirsty regions, and these, in their turn, evaporate their rains for regions further east, and this process is many times repeated before the interior of the continent receives

its scanty supply. In consequence, however, of the more rapid evaporation, the supply is greater in summer than in winter.

The rapidity of evaporation is greater in summer than in winter from humid surfaces, for two reasons, a higher temperature and dryer air; and if the quantity of water passing to the ocean in the Seine for the whole year was found, by careful measurement, to be only about one-fifth of that which falls in rain over its basin, we may safely say that during the summer not one-tenth of the fall passes to the ocean.

This reason will apply with peculiar force to this country. Take, for example, the valley of the Ohio. In the winter season the Ohio river discharges probably ten times as much water as it does in the summer, and, yet even in the winter it does not discharge near all that falls, for evaporation goes on so rapidly in the coldest weather (though not so fast as in warmer) that snows several inches deep sometimes disappear by evaporation, without melting, and leave the ground dusty.

Now the quantity of rain in this valley is about the same in summer as in winter, and if we suppose that even one half the fall is carried off by the river in winter, then only about one twentieth is carried off during the summer, and this small amount is all that is needed from a foreign source. During the winter all our great rain and snow storms are ushered in by eastern winds from the Atlantic, going to meet the storm while it is yet in the valley of the Mississippi, taking to the up-moving current of air under the storm cloud an ocean of vapor to be condensed, and fall in rain or snow. In this way, no doubt, much more vapor is furnished from the Atlantic in winter than in summer; much more is needed then, because the evaporation is less, and much more is carried off to the ocean by the river.

217. It is known that much more rain falls on land than on an equal surface at sea; but it is not generally acknowledged that evaporation is more rapid on land while the surface is humid than at sea, and yet it is, for this reason alone, if for no other, that the air is generally dryer on land than at sea. Nor is it necessary that the surface should be very humid to produce this effect, as any one may ascertain by putting a wet rag around the bulb of a thermometer and swinging it in the air. He will find to his surprise, that after the rag has become apparently nearly dry both to the sight and touch, the thermometer will continue for a short time to show that evaporation is going on just as rapidly as when the rag was saturated with water. This was a result which had not been anticipated when first observed, and, therefore, I tried the experiment many times, and always with the same result. During the day, also, the surface of humid ground in the summer becomes much more heated than the surface of deep water, and on that account evaporation will go on much more rapidly from the land than from the sea. The reverse of this takes place in the night, and probably these effects will nearly balance one another. But even if it should appear that less is evaporated from land than from sea for equal surfaces, in consequence of the many arid regions in different parts of the earth, still there is no difficulty in finding enough of vapor generated in the northern hemisphere to produce all the rains in it, without "regarding the extra tropical regions of the northern hemisphere as standing in the relation of a condenser to a grand machine, the boiler of which is in the southeast trade winds,"* sending its vapor through tubes which pass for thousands of miles through air at a temperature below zero, in the upper current of air without condensing

* Maury's Physical Geography of the Seas, page 110.

it, until it is brought down to the surface of the earth on the north side of the calm belt of Cancer, into a region from sixty to a hundred degrees warmer than the one through which it passed.

218. Nor, in accounting for the rains of Europe, is it necessary to adopt Dove's notion, "that the mass of air projected into the upper current moves directly from the West Indies to Europe," and that the air which ascends in the tropics descends again in higher latitudes; and that the increase of temperature, which this occasions is produced, when the aqueous vapor, which was formed over the surface of the tropical sea, returns to the earth in the shape of rain, and in so doing sets free the heat which had become latent in the formation of the vapor; Europe, therefore, resembles a condenser to the Caribbean sea."*

Some sixteen or seventeen years ago (I state from recollection) M. Dove sneered at my theory for pretending to explain under one law the *formation of clouds, rain, hail, and snows, changeable winds, and barometrical fluctuations*. Well, I will forgive this distinguished writer if he will only read this report, and then declare that there is no philosophical argument to be found to refute my theory; and that that is the reason why a refutation never has been attempted by its opponents, except by sneers.

Or, if he thinks differently, then I shall be satisfied if he attempts to refute it by solid argument.

If M. Dove finds reason to believe that the air comes down in the belt of high barometer, it will change his views on many other points, and at least induce him to review the whole subject. He says: "The southwest wind does, in fact, prevail in the northern temperate zone, as does probably the northwest wind in the southern temperate zone."—(Page 20.) If so, we have the same theoretic reason for believing that the upper current over the temperate zones is towards the tropics, as it is towards the tropics over the torrid zone. But, even if this is not so, I respectfully ask M. Dove to consider how it is possible for air to rise in the Caribbean sea high enough to overflow the trade winds without condensing a large portion of its vapor, when it is known that even in the torrid zone the temperature of the air sinks about one degree for an elevation of one hundred yards? And again, suppose it does retain a large portion of its vapor, it must do it by remaining at a very high temperature; and if so, how can it sink down through colder air? and if it should sink down, how would it condense its vapor in becoming one degree hotter for every hundred yards of its descent? And suppose it does condense its vapor in descending, why does it not condense it all the way to the surface of the earth, and not stop at a particular plane, where the base of the cloud remains on nearly a horizontal level?

If it is answered that the air does not begin to descend till it becomes colder than the air through which it is descending, and that in thus becoming cold it condenses its vapor and descends at the same time, then I ask why does not the barometer rise under the cloud, and why does not the air blow outwards below from the centre of the storm?

Does the air, in going up into the upper regions over the Caribbean sea, not become as cold as if it had to pass over the tops of snow-clad mountains? and if not, how much colder does it become in its upward motion? and how much of its vapor does it condense before it leaves the top of the storm cloud?

* Dove's Distribution of Heat, page 18.

These questions ought to be answered by any one before he attempts to build up a theory connected with them.

The learned author will permit me to say, that these questions have been answered by my investigations with the nephelescope, detailed in my third report, and copied also into this. I commend them to his notice, and, as the instrument is simple and easy of construction, perhaps he will repeat the experiments, and add the weight of his name to their accuracy and importance, or, if there is any inaccuracy, correct it for the benefit of science.

I will merely add, in taking leave of the author, that if my theory was worthy of a sneer when first announced on account of its pretension to explain six phenomena under one principle, the evolution of latent caloric in the condensation of vapor, how much more worthy of a sneer is it now, when it professes to explain several hundred phenomena under the same principle?

To return to the inquiry, where does the vapor come from to make the rain that falls on land? The answer is, that no more is needed to come from the sea than goes to the sea by the rivers, which, in the case of the Ohio valley, which we have been considering, is not one-twentieth of the whole that falls in rain during the hot months; all the rest is sent up into the atmosphere by evaporation to make more rain of.

One would suppose if there was any difficulty on the subject it would be to find out what became of all the rain that fell in the hot months when so little of it was seen going off to the ocean by the rivers.

It will not satisfy the scientific inquirer to tell him that it is absorbed by the thirsty ground; for if it is absorbed when it falls, it does not stay there, and does not pass off in the rivers to any considerable extent.

And yet so great does the difficulty seem to a distinguished writer of our own country to find vapor to make rain in the valley of the Mississippi and the St. Lawrence, that he could find no region to supply it on this side of the southeast trade winds of the Pacific ocean.

According to the estimates of the quantity of water flowing between the piers of a bridge in the channel of the Seine, a single rain of $5\frac{1}{4}$ inches deep over the basin of that river above Paris would furnish water enough to supply the Seine for a whole year.

Now, as was said before, in all our great storms in the cold months, the wind comes in from the eastward, and advances even beyond the Mississippi, carrying with it a flood of vapor from the Atlantic, where the dew-point is about four or five degrees below the temperature of the air to be condensed in the up-moving current of air under the storm cloud.

Surely we may infer, from analogy with the climate of France, that four or five such storms as these, each throwing down an inch and a half of rain, will be sufficient to supply the rivers with all the water which they send to the sea in a whole year.

In the summer very little vapor is needed from the ocean, as very little water is carried by the rivers from the land in that season; and it is not necessary that the wind should prevail from the nearest ocean towards the land to furnish vapor enough from the ocean to supply the deficiency on land. It is sufficient that it blows from the sea at moderate intervals, and that the vapor which it brings with it be condensed into rain before the wind which brings it passes out of the country. Now, such is the case in the summer with the winds from the Gulf of Mexico. Indeed, they may be said to be the prevailing winds.

But if the theory which is given in this report is the true one, and rains are really produced

by up-moving columns or currents of air, then the whole difficulty as to the production of more rain on land than on an equal surface of sea is easily removed. The elevations on the land in the form of mountains and hills will induce up-moving currents. These up-moving currents, under favorable circumstances, will produce rains; and wherever there are up-moving currents, there are in-moving currents below and out-moving currents above—the in-moving below, moist; the out-moving above, dry. And as these up-moving currents with rain are more numerous on land than at sea, there are more in-moving currents from the sea towards the land below, and thus more vapor is brought there to condense into rain.

I am well aware that this argument will have no weight with those who do not believe that rains are only produced by up-moving currents as well on plains as over the “tops of snow-clad mountains.”

When I first propounded the theory here advocated, I employed in my calculations the various physical laws then recognized by the scientific world as having been established by experiment. These were the specific caloric of air 0.267, the latent caloric of steam 1000° , at the temperature of 212° or 1212° at zero of Fahrenheit, the expansion of air from increase of temperature $\frac{1}{448}$ of its bulk at zero for each degree of increase, the reduction of temperature of air from expansion from diminished pressure 90° for an expansion into double the bulk, commencing with the temperature of 90° .

Now, there is one problem connected with this subject which I am unable to solve, and that is, how it has happened that two such distinguished writers as Mr. Dove and Lieutenant Maury, in discussing the subject of rains and winds, could have entirely ignored the last mentioned law? Both these writers acknowledge that up-moving currents of air exist—Dove over hot arid deserts, and Maury in the temperate zones, from the necessity of the case—as the tropical winds advance towards the poles, where the degrees of longitude contract, so that more than one-half the air which leaves the tropical belt of calms must rise and unite with the current above before it reaches the polar circle; yet neither of these writers says one word of the condensation of vapor, as it goes to where the temperature of the air in which it ascends sinks far below zero.

219. MM. Barral and Bixio, in their celebrated and highly interesting balloon ascent on the 17th July, 1850, from Paris, found their thermometer fall from $17^{\circ}.5$ plus to 39° minus in reaching an elevation of 7,016 metres—that is, $101^{\circ}.7$ Fahrenheit in 7,600 yards. Fifty-two of these degrees, a little more than the half of the whole, were made almost suddenly on reaching the upper part of the cloud in which they had ascended from its base near the surface of the earth. At 6,800 yards high the thermometer of Fahrenheit was $11^{\circ}.7$ above zero; and on going eight hundred yards further, at which time they reached the upper part of the cloud and saw blue sky above them, the thermometer was down to 38° below zero. They ascended from the earth just after the fall of a heavy shower, and their ascent is most precious on this account alone, if for no other: it proves the law almost numerically that I have endeavored to prove by experiments with the nephelescope, of the difference of temperature between the air in a forming or recently formed cloud, and the air in the outside of the cloud at the same height.

Now, if air goes up in the torrid zone and passes thence to Norway, I respectfully ask, how it can carry vapor with it to heat that coast by condensation, after it comes down, much of it from heights far beyond the region where these aeronauts found the temperature 38° below zero of Fahrenheit? It is not necessary to go beyond the Atlantic to find the region where the vapor is

generated which gives or helps to give to the coast of Norway an abnormally high temperature by its condensation. Part of the high temperature of this coast is due to the warm waters of the Atlantic, not so much by its direct effect, as by imparting its heat to the air which blows from it on that coast. If its abnormally high temperature depended entirely on caloric evolved by the condensation of vapor, Cape Horn and the southern region of South America ought to be even warmer than the western coast of Europe in the same latitudes ; but it is not so warm, no doubt, because the sea around it is much colder. Norway has prevailing S.W. winds, and Cape Horn N.W., equally favorable for heating, so far as direction is concerned ; and, besides, Cape Horn has the advantage in winter, as often as east winds blow at the two places ; for, at Cape Horn, the wind then blows from a comparatively warm ocean, and at Norway it comes off a very cold land.

In both cases the snow line is much lower on the windward side of the mountains than on the leeward, as *it is on every snow-topped mountain in the world*, whatever kind of radiating surface there may be to the leeward. Indeed, very often in the summer the heat liberated by the condensation of the vapor is melting the snow to a higher level on the leeward side of high mountains, while it is snowing on the windward side, and lowering the snow line, the cooling effect of the snow falling from a great height and excessive cold, at the same time preventing the snow from melting on the side where the principal part of the snow falls.

220. General Mosquera, in his interesting Memoir on the Physical and Political Geography of New Granada, mentions a remarkable peculiarity in the climate of the lofty plateau between the eastern and western Andes, a few degrees north of the equator. In the two rainy seasons near the equinoxes, on the plateau, it is dry on the mountains ; and during the dry seasons on the plateau, near the solstices, it is the rainy season on the mountains.

He says, page 28 : " When the dry season prevails on the plateau, the great elevations on the mountains are covered with clouds, and there are violent storms, accompanied with hail ; this is the period when there are floods in the rivers which flow from the Cordilleras ; the level of the perpetual snows is raised on the snowy Cordilleras, but in the time of the rainy season on the plateau the Cordilleras are dry."

It was, no doubt, the heat of the clouds that melted the snow during the rainy season on the mountains ; for he says, page 85 : " In the paramo of Puracé, about 4,400 metres high, I have observed that when the air is 41° Fahrenheit, the snow was one degree and eight-tenths below the freezing point, with a bright sun, and the wind from northeast ; and *while the sky was unclouded, there was no thawing.*"

Twenty-five years ago, when I was making a series of experiments to ascertain the dew-point from the wet-bulb and dry-bulb thermometer, I have seen the thermometer that I had prepared the evening before, with a film of ice round the bulb, continue below the freezing point without melting the ice till the temperature in the shade rose to 37° . In two cases of this kind, I found the dew-point at 10° , when the temperature of the air in the shade was 37° , and the ice-covered bulb was 31° . I found that the same formula which I had adopted from experiments for temperatures above the freezing point gave the dew-point here ; and I inferred, therefore, that the evaporation from ice is about one-ninth less than evaporation from water to produce the same degree of cold, for this is nearly the ratio of the caloric of fluidity to that of elasticity. The wet-bulb was at the same temperature as the ice-covered bulb, 31° .

I have more confidence in this result, as I frequently succeeded in getting a thermometer with a wet rag, without freezing, to hang alongside of the one covered with a film of ice; and these two would show the same temperature from 27° to 32° ; below 27° , the wet bulb would always freeze, though I understand the wet bulb has been seen as low as 26° without freezing.

When experimenting to ascertain the dew-point by means of the wet bulb, I always swung both thermometers moderately in the air, having first ascertained that a moderate movement produced the same depression of the wet bulb as a rapid motion, which is not at all the case when the thermometer is at rest in still air.

On writing this sentence, I stop to perform the experiment again, and I find the temperature of my room is 71° ; the temperature of the wet bulb at rest, 60° , and when swung moderately in the air it is 56° ; and when swung rapidly, it is still 56° ; and the dew-point, taken by finding the highest temperature at which the vapor in the air will condense on a thin metallic tumbler, with water in it, cooled down artificially for the purpose, is $43\frac{1}{2}^{\circ}$.

In ascertaining the dew point in this way, I breathe on the outside of the tumbler, and then wipe off the condensed vapor of the breath, for I have frequently found when that is not done the tumbler has to be cooled down a degree or two below the dew-point before the vapor in the air will begin to condense upon it. The highest temperature at which the vapor will condense I call the dew-point.

I take occasion here to commend my empirical formula for the dew-point to the attention of meteorologists. It is acknowledged that the theoretical formula is incorrect in parts of the scale; mine will be found nearly accurate for all temperatures of the wet bulb between 70° and 20° . The formula is given in another part of this report.—(117.)

Above 70° a larger number than 103 must be used, for example: when the wet bulb is 72° , 104 must be used as a multiplier; and when the wet bulb is 74° , 105 must be used; and when the wet bulb is 76° , 106 must be used; and it is certain, that at higher temperatures still higher numbers would have to be used as multipliers; but experiments have not been made to determine this point exactly.

As to the cause of its being fair on the mountains during the rainy season on the plateau, I will suggest a hypothetical one: General Mosquera nowhere in his Memoir speaks of the direction of the wind at the different seasons, but I think it probable that during the rainy season on the plateau the wind comes from the north, and if so, the air will be compelled to rise gradually up the slope of the country from the mouth of the Magdalena to the lofty plateau, and, of course, will produce rain in its ascent, and swell up the air over the plateau by the caloric liberated in the condensation of the vapor. This will diminish the quantity of air which would otherwise flow from the east across the eastern range of the Andes, which produces the rain on that range during the other two seasons when it is dry on the plateau. If the air blows from the east during the rain on the mountains, it is easy to see from the theory why it does not then rain on the plateau west of the mountain, for the air which crosses the mountain curves downwards in crossing the plateau, and whatever cloud may be contained in it, on leaving the top of the mountain, will be dissolved or evaporated long before it reaches the level of even that lofty plateau.

The same cause prevents its raining in the valley east of the coast range of mountains in California; when the wind blows from the west across those mountains, the wind slopes down-

ward in coming over that range to conform in some measure with the surface of the ground over which it moves, and passes on without raining till it reaches the Rocky mountains, and then it rains again.

If there was a mountain in the midst of this valley, no doubt there would be rain on it and in its vicinity, as there is where there are mountains in the great plains in South America, even in the dry season.

Even in the Great Sahara of Africa, wherever mountains are found, there are great rains occasionally.

In latitude 25° north and 10° east, almost in the middle of that desert, Richardson, after leaving the oasis and mountains of Ghaut, travelling south about a day's journey, had a cool south wind on the 1st of August blowing towards that oasis, and on the 16th of August, when he reached the tropic of Cancer, 9° east, he had "a violent wind and rain storm, in the neighborhood of mountains." And he says, page 221, "there cannot be a doubt that occasionally an immense quantity of rain falls in every region of this great desert." I think he ought to have added, "where mountains occur."

It is not for want of vapor in the air, but for want of mountains on the surface of the earth, that such vast regions in the African desert are destitute of rain. I mean in the summer season, when the belt of high barometer is on the north side of the Mediterranean sea, and the wind from that belt blows over the surface of that hot sea, charging itself up with vapor and carrying to the great belt of rains south of the Sahara all except the small portion precipitated over insulated spots where mountains are found. This reasoning does not apply to the winter season, when the belt of high barometer is over the desert, and the harmattan, which blows on the western coast frequently at that season from the desert, is always found to be a very dry wind, but never very hot.

"The harmattan is a cold and very dry north or northeast wind, which blows for a few hours at a time, at intervals of three or four weeks in the dry season. It feels decidedly cool at Yoruba, (west of the mouth of the Niger,) and on one occasion it caused the thermometer to sink to 60° . The dryness causes excessive evaporation. I have seen the harmattan, in a few hours sink the wet bulb 25° below the dry, though at Ijaye it stands only 6° , and at Ogbomoshaw, 10° below the dry bulb".—(Bowen's Central Africa, p. 233.)

At page 223 Mr. Bowen says "the harmattan produces frost and even ice at Hause, so say the natives, and Clapperton affirms the same."

The reason why this wind is so dry is this: The belt of high barometer is over the Great Sahara at the season of the year when the harmattan blows, and the air there descending brings down its low dew-point with it, and not meeting with moisture at the surface of the earth, it thus becomes or rather remains an exceedingly dry wind, blowing towards the region of rain near the equator.

NOTES CONFIRMATORY OF PRINCIPLES ADVANCED IN THIS WORK.

1. Mr. Piddington says, page 161, "There is an appearance of the clouds sometimes seen in hurricanes at the passage of the centre which I trust in future will be noted and registered when it occurs. In the great Calcutta storm of June, 1842, at the time the centre passed over that city it was calm, and I drove out on the esplanade. In the zenith it was so thick that the

direction of the scud could not be determined, but to the east and northeast it was slowly moving to the west and southwest, while in the south, from thick heavy masses of clouds the scud was rising and flying to the north and northeast.

And in the severe hurricane experienced at the Mauritias on the 7th and 8th of March, 1845, the observer says: "Finally, the whirlwind was distinctly shown when we were in the actual centre. We then observed all around us winds in all directions without feeling the effect of any; the clouds at sea (which was south of the observer) were moving to the north, and those of the mountains to the south, while at the zenith everything was perfectly stationary." Mr. Piddington thinks this ought to convince the followers of Mr. Espy and Professor Hare of the circular motion in hurricanes in America, for says he, "I do not recollect that any European authority in science has doubted of its existence."—(Sailor's Horn Book for the law of Storms, by Henry Piddington.) [See 187.]

Dr. Buist, speaking of the western coast of Hindoostan, says: "Our gales of the 7th April, 1843, and 27th of May, 7th and 19th of October, have all been traced to the other side of India, travelling very regularly across, at the rate of 20 miles an hour.

The fall of the barometer which occurred here on the 4th corresponded with that on the Coromandel coast on the 1st.—(Madras Journal, vol. 15, p. 202.)

2. Captain Wilkes, page 11, in crossing the rainy belt from 4° to 12° north latitude, 6.15 inches of rain fell in ten days, mean barometer 29.987, temperature of $79^{\circ}.6$, water $82^{\circ}.07$, degrees of moisture 73.4, winds light and variable, generally from the northward, and westward, though inclining to calms. Movement of the upper stratum of clouds to the westward during our traverse across the zone. Southeast trade winds commence at 3° north.

3. Page 17, at Orange Harbor, 30 miles north of Cape Horn, rain fell for thirty consecutive days in February and March, the season in which there is least rain, 8.26 inches. The greatest fall in 24 hours was 1.08 inches.

Page 20, on the coast of Chili, from latitude 35° to 42° , a northern monsoon prevails in the winter of that region, and a southern monsoon in their summer. The southern monsoon is a dry wind and its daily duration is generally confined to 5 or 6 hours, from 11 a. m. till 4 p. m. A calm then succeeds, and towards morning in this season the land wind is felt with almost the same certainty. Their winter monsoon blows moderately from the north and northwest, has a high degree of moisture, and the rainy season north of the river Manle is June and July.

At Calao the wind blows almost constantly from the south, from November till May, moderately without intermission, whilst in their autumn and winter, though stronger, it is often interrupted by light rains from the north, and on their occurrence the "garua" is immediately formed, and towards evening, a heavy deposition takes place. The sun has seldom power enough until near midday to dissipate these mists, which render the climate during their winter damp and cold.

We found the vapor plain on this coast to be elevated above 1,250 feet. Below this point vegetation is confined to the winter months, unless moisture is supplied by art.

4. Wilkes found the barometer lowest between 63° and 66° south latitude. At a mean in their latitudes it was about 29.00. He spent one day in about 67° , and the barometer on that day never sunk below 29.20, and for several days between latitude 66° and 67° the barometer stood above 29. Whereas, between 63° and 64° , on one day the mean of the barometer was 28.638.

In latitude 66° , 67° , near the icy barrier, the wind was constantly from the southward. Whereas, in 59° , 60° , it prevailed from the northward, and much snow fell in intervening latitudes.

In the report of the B. Assoc. for 1847, Mr. S. H. Thomas, of Alton, Norway, says the mean height of the barometer increases from the equator to $36^{\circ} 13'$ north latitude where the maximum is found. From this to $68^{\circ} 24'$ it decreases in height and then increases again towards the poles.

The observations of Middendorff in the remote north of Siberia, on the bank of the river Baganida, (presqu'île de Taimour,) give the barometer in Kuppfer's Appendix for 1846, May, 29.741; June, 28.868; July, 29.314; August, 29.408.

5. Foissac's Meteorology, vol. 2, page 225. When the sky is clear during the summer the dryness of the air favors evaporation to such a degree that the volcano of Aconcagua, to the northwest of Valparaiso, (near latitude 30° south,) is sometimes entirely deprived of snow, though it is 450 metres higher than Chimborazo. [This is the belt of high barometer.]

The most remarkable feature of the central plains of La Plata, south of Tucuman, bordering on the Cordereve, as those of San Juan, [which is just east of the Andes and on each side of latitude 30° ,] is the great scarcity of water and the total want of grasses, over vast regions 50 leagues in extent, embracing a surface of more than 166 square leagues in extent.

In some parts of the Trapisias rain has been known not to fall for 18 months. Dew, which is abundant on the Chilian side of the Andes, is unknown here. The distinguishing feature of San Juan, La Rioja, Calamarea, and Santiago del Estero, is aridness.—(Jour. Roy. Geog. Soc., volume 9, pages 405, 406.)

6. Encyclopedia Metropolitana says, the snow line on the western side of the Scandinavian chain of mountains, in latitude 67° , is 1,000 feet lower than on the eastern side, and the difference exists with respect to the final limit of trees. [This is the case with the snow line everywhere; it is lower on the windward side.]—(See 55 to 57.)

7. Lieutenant Sullivan, in a paper on the Falkland Islands, (Piddington, p. 29,) describes the gales at Berkely Sound as commencing N.E. and veering to N.W., and ending S.W.

At the east of Cape Horn southwest gales veer to the northwest.

8. Cunningham's Ladak, p. 172. In Ladak the dry wind is nearly always southerly and westerly, both in summer and winter. This fact was partially observed by Alex. Gerard, who remarks that, on peaks upwards of 20,000 feet, and at heights 16,000 feet, the winds were always west or southwest.

The same fact was noticed by my brother, Captain Jos. Cunningham, who resided nearly a whole year, including one entire winter, in the districts of Upper Kanawar, Spiti, and Churanti; he says "a northerly wind was a rare occurrence." These were day winds which were frequently strong, but at night there was generally a breeze from north and northeast. This was at a height of about 13,000 feet. In Bode's translation of Khanekoff's Bokara, p. 48, the north and northeast winds are so constant at Bokara that during the eight months of my stay there I do not recollect that the wind blew more than ten times from the south—October to April. [This wind blows towards the Hindoo Kush mountains, and causes the snow line there to be lower on the north side. Where does this wind come from? Is it part of the wind which blows over the Himalayas from the southwest?]

9. In Mr. Murchinson's address before the Geological Society, 1852, he says: "My friend,

Professor Oldham, in writing to me from Churra Poorjee, in the Khassya hills, north of Calcutta, states that the rain fall is there about 600 inches per annum, 550 inches of which descends in the six rainy months, commencing in May; and that in one day he measured a fall of 22.5 inches! This remarkable phenomenon, it appears, was previously known to Drs. Hooker, Thomson, and other scientific men.

10. Major Bernard says, pages 164, 165, the prevalent winds on the Isthmus of Tehuantepec are from the northward, and, on reaching the table lands, they deposit in rain the greater portion of the watery vapor which they held suspended, and on crossing the summit-level the increased cold condenses almost the remainder.

On reaching the southern slope the mists are converted into invisible vapor so as to present to the eye of the spectator the appearance of the rain clouds suddenly vanishing into thin air when they pass southward over the hills. [Because they descend and come under greater pressure.]

The cool wind of the north has a tendency at all times to occupy the lower stratum of the air owing to its density, and hence it is that it sweeps down the narrow gorges on the southern side and carries with it clouds of dust to the shores of the Pacific.

The rains often extend out into the trade winds, and often to a considerable distance both north and south of the calm belt.—(Maury's Physical Geography of the Sea, p. 179.)

11. On the west side of the Andes, above Lima, (Smith, vol. 1, page 258,) the dwellings made of mud, cane, and wicker, and thatched with a sort of living lichen, show that here the climate is still, dry and warm, and the place sheltered from rude winds and storms.

We have seen the cottager, who occupied the hut immediately at the foot of the arduous ascent which commences here, look with indescribable complacency, as we did from this little corridor, at the rain pouring in torrents a few hundred yards above us, while his own little snug retreat was hardly reached by a gentle sprinkling.

12. Jarvis' Sandwich Islands, p. 7. The great height of the mountains intercepts the clouds which condense against their sides, and to the windward and on the high lands occasion abundance of rain, while the leeward portions during most of the year suffer from drought. During the winter months, when the trades are partially interrupted, showers occur more frequently on the plains.

13. Dr. Miller, on the Meteorology of the English Lake District, Trans. Roy. Soc. of Edinburgh, 1853, 1854, found the evaporation from ice greater than from water, because the dew-point was very low when the temperature was below 32° . In the first six days of January, 1854, the loss from the frozen contents of the gauge was 0.219 inches, or .036 per day.

In Barrows' Straits, latitude $74^{\circ} 40'$, longitude $44^{\circ} 16'$, the wind was northerly more than four to one in December, 1850, as shown by a journal kept on board her Majesty's ship Sophia; and in January, 1851, it was northerly every day but one; in February every day but three; in March every day but four. In the other months the wind was more variable.

14. In the 16th volume of Pinkerton's Voyage and Travels, page 869, Park says: The whole of my route, both in going and returning, having been confined to a tract of country bounded nearly by the 12th and 15th parallels of latitude, (in Africa,) the reader must imagine that I found the climate in most places extremely hot. In some places the country ascends into hills; the air is at all times comparatively cool, yet none of the districts which I traversed

could properly be called mountainous. About the middle of June the hot and sultry air is agitated by violent gusts of wind, (called *tornadoes*,) accompanied by thunder and rain.

These usher in what is called the rainy season, which continues till November. During this time the diurnal rains are very heavy, and the prevailing *winds are from the southwest*. The termination of the rainy season is likewise attended with violent tornadoes, after which the wind shifts to the northeast, and *continues to blow from that quarter during the rest of the year*.

About this time is felt the harmattan, a dry and parching wind blowing from the northeast, and accompanied by a thick smoky haze. This wind parches up everything exposed to its current. It, however, is reckoned very salutary, particularly to Europeans, who generally recover their health during its continuance.

Journals of the weather for 1825 and 1826, kept by Clapperton and Lander, in latitude about nine or ten degrees north, on the Niger and near it, show a true monsoon—northeast during the winter, without rain; southeast in summer, with rain—agreeing with Mungo Park's account. The mornings of the winter were almost always hazy. [Was this haze the extension of the clouds above from the rain in the south?]

15. In Kotzebue's Sound, about latitude $66^{\circ}.5$, longitude 162° or 165° , the barometer stands at about $30^{\circ}.20$ with a southeast wind; and with a northeast wind, and most severe weather, it stood at $29^{\circ}.50$ in August. With southeast wind the weather was gloomy. At St. Lawrence Bay, latitude 65° , longitude 171° , the barometer sunk to $28^{\circ}.70$ during a southeast storm on the 27th August.

16. Mr. Thom, page 262, says: "In June, 1843, when about forty miles distant from the coast of Africa, we encountered a very unsettled state of the weather. The wind was northwest off the land, and had been so for some days, and from time to time brought with it heavy dark masses of cumulo-stratus clouds, sweeping along the surface of the sea, preceded by severe squalls, accompanied by lightning and thunder, and discharging torrents of rain. As these brief but fierce storms passed us to the southeast, the wind gradually veered by southwest to south-southeast, and after lasting about an hour or so, died away, and was replaced by the northwest wind. In the first half of these miniature tempests the air felt hot and muggy; but as they began to subside, the thermometer fell ten or twelve degrees. For twenty-four hours a continued succession of these took place, and during the night the display of electricity was truly terrific. For half an hour at a time the masts seemed to be enveloped in lurid flame, and forked lightning was seen darting from the leaden-colored cloud into the mastheads. So continuous and flickering was the glare that several persons imagined the ship was on fire. On two occasions the decks were covered with hailstones of immense size, which fell at the moment when the thunder was deafening, and the electric fluid was evolved in an intense degree, and the storm had lulled to a dead calm, while a heavy jumble of sea was knocking the vessel about. In the last of these 'cape squalls' the wind went round from northwest to south-southeast so suddenly that the ship's head could hardly be paid off to prevent the topsails being taken aback, and it ushered in a tremendous gale from the southeast, which blew with fury for twelve hours. We were then very near the coast.

"In the Mediterranean, we carried a strong southeast gale with us from Sicily till abreast of Sardinia, when, on the 3d September, 1833, it blew in violent squalls, with heavy lowering clouds coming up on the wind; and towards evening the lower clouds were seen flying overhead

to northwest at a prodigious rate, while over these another stratum was drifting in an opposite direction. About sunset we were suddenly enveloped by a canopy of black and awful looking clouds, and the thunder pealed as if many hundred pieces of artillery had been discharged at once, when, all of a sudden, from blowing a hurricane it fell calm. A waterspout was suddenly formed (discovered) on our larboard quarter, while the schooner was without a breath of wind to move away from this new danger. The dark cloud overhead was fast drawing up the water in a vapory stream, as if from a boiling cauldron. Soon afterwards the northwest gale set in, in gusts and squalls, right in our teeth. The calm between the southeast and northwest gales lasted about an hour; and, as the latter wind set in, a bright line on the northwest horizon, showing the last rays of twilight, appeared, and the thick bank of clouds gradually rose in an arch from the same quarter, and was carried to the southeast, and by midnight the stars were seen, although it still blew a heavy gale." [The centre of the storm passed over the observer.]

WILKES' THEORY OF THE WINDS.

17. "In crossing the space between the northeast and southeast trades, the changes of wind are at times sudden, and require constant attention; sometimes severe and shifting squalls are experienced; one of them happened to us in the Atlantic, latitude $9^{\circ} 30'$ north.

"The squadron was sailing in close order, with a fresh breeze from the southeast, when the vessels were taken suddenly aback by a squall from the southwest. In a few minutes we had the wind from different quarters, so that it required, during the time it lasted, good management of the vessels to avoid running into each other."—(Page 57.)

It would appear, from this account, that the winds "from different quarters" blew towards each other.

"On reaching latitude 30° south, on his way from Rio de Janeiro to Rio Negro, the air assumed a very perceptible change in respect to its hygrometric state, being now much drier, and giving a feeling of more elasticity than we had experienced for some months."—(Page 50.) [This is in the belt of high barometer.]

"Our passage through the Straits of Le Maire was effected in a few hours, though we were not favored with good weather. We entered the Strait with a fair wind and all sail set, but were reduced, before we left it, to close reefed topsails, in consequence of the squalls that came rushing out of the ravines of Tierra del Fuego as we passed them." "Near the middle of the Strait the williwaws are not so violent as near the high lands."—(Page 66.)

18. "After doubling Cape Horn, if the longitude of 75° west has been reached, it would be better to stand to the northward again, and close with the coast; no apprehension of lee-shore need be entertained. All navigators who have had any experience on this coast, from Cook down, agree as to the winds not "blowing home."—(Page 66.)

It is highly probable that when the wind blows strongly from the westward on the southern part of South America, it rains on the western slopes of the mountains; and if so, the weight of the falling drops will push out the air below towards the west, whilst the air above, even at the elevation of a few hundred feet, is blowing over it strongly from the west. This lower wind from the east, in case of a very heavy fall of rain on the slope of the mountains, may be very strong near the shore, and gradually die away a few miles out at sea, and thus the western wind out at sea is prevented from "blowing home." [That is, up to the very coast.]

"In the summer, heavy gusts off the highlands come rushing down with great force into the harbor of Valparaiso, causing vessels to drag their anchors."—(Page 70.)

"On the Mexican coast, during the summer, from May to September, when the south and southwest monsoon prevails, squalls and tempests prevail, which come from the high land of the isthmus, and rush with great violence over the sea, though they are of short duration. This is the rainy season; but with the north and northwest monsoon in the winter it is dry. This northwest monsoon never goes beyond the Bay of Panama."—(Page 19.)

19. "The eastern shore which properly bounds the Greenland seas can rarely be approached by the whalers, as the accumulated stream of ice, which in summer is constantly drifting from the northeast, creates a formidable barrier."—(Adventures in the Polar Sea, page 43.)

During the short time that Captain Parry and his men were endeavoring to reach the north pole from the northern shores of Spitzbergen, in 1827, "*there fell as much rain as they had experienced during the whole course of seven years in a lower latitude.*"

The wind was constantly south for several days and then changed to north, and the ice on which they travelled moved on some days after the change of the wind further south than they travelled north, so that not having reached latitude 83° , they were obliged to return."—(Page 290, of Adventures in the Polar Sea.)

20. In the *Annuaire Météorologique de la France*, for 1852, there is an account of a great hail storm which occurred on the 23d August, P. M., 1850, in the Canton of Vaud, near the Lake of Geneva, which travelled towards the northeast with a velocity of about 60 miles in an hour and a half. No account is given of the state of the barometer within the storm at the moment of its passage, but on each side of the storm, both northwest and southeast, the barometer rose slightly on that day, and M. Rod. Blanchet, who gives the account, says that the *wind blew inwards from the northwest and southeast, as also from the southwest and northeast in the borders of the storm towards the centre. M. Blanchet has exhibited this fact by arrows pointing inwards on the chart which he has drawn to show the region of the storm.*

The Rev. M. Blanchet, who lives at Rances, about five miles from the borders of the hail on the northwest, says, we were spared from the ravages of the hail. A large cloud came up from the southwest and poured down a flood of rain. *It ordinarily happens in such cases that the wind arises from the northwest. This wind drove off the hail cloud.*"

When the hail began the vein was very narrow, but it became wider as it progressed to the northeast, and where it terminated it was six or seven miles wide. In many places it fell by instalments, separated only a few minutes.

It seems quite certain that the hail fell down through the cloud in this case, and was more violent near the middle than at the sides; the up-moving column was too wide to throw the hail outwards at the sides, so the drops of rain must have been carried up high enough to freeze in the cloud.

Mr. Blanchet says that, at Lausanne, when a storm is gathering on Mount Jura on the west-northwest, *one sees regularly the ascending current of air push the cumulus vertically in space to a prodigious height.*

21. *Annales Hydrographique*, vol. 6, p. 325. On the coast of Chili, from 26° to 44° south, there is a well defined monsoon, north from May to September, and south from October to May. These monsoons extend out to sea between two and three hundred miles. From latitude 26°

south to near the equator, the wind blows all the year from the southward, varying only from south-southwest to south-southeast, with a sky always covered with clouds, with fogs generally in the morning and copious dews in the night. Near the coast, however, from Valparaiso northward to Peru, there are sea and land breezes, in the day and night. The regular trades are hardly felt in the Pacific within five or six hundred miles from the coast.

At Callao, (about 10° south,) squalls from the mountains are never felt, though they are frequent on the coast south of that town.

In the Bay of Panama, the winds are from the north or northeast from September to March, and south and south-southwest during the rest of the year. The rainy season commences in April or May. The rain gradually increases, and is very abundant in June, July, and August, then diminishes, and terminates in November or December. During the dry months they have sea and land breezes; but not in the very wet ones.

From the western extremity of the Bay of Panama to latitude 30° on the coast, they have pretty well defined monsoons, with the winds from the northward, varying from northwest to northeast, from November to April; and from the southward, varying from southwest to southeast, from May to October. The southerly monsoon is rainy, sometimes raining twenty-five days in succession, between 10° and 20° north, the wind being then frequently southwest, with squalls like those on the coast of western Africa. In February and March, however, between latitude 13° and 15° it is subject to prolonged calms, extending two or three hundred miles from the coast.

22. From latitude 40° to 50° the winds are variable, but prevailing from the southwest to the northwest, with bad weather while the southwest prevails. According to observations made at New Archangel, latitude $57^{\circ} 3'$ north, it appears that the predominating winds in the winter are from the east, accompanied with rain and snow whilst on the opposite coast of Kamtschatka, the winds are west in the winter, and in the ocean between these places the prevailing wind is southerly, and *north of Behring's Straits, in the Arctic ocean, the north wind prevails.* [Blowing towards the belt of low barometer.]

In the summer, at Kamtschatka, the east wind prevails variable, to northeast and southeast, with foul weather, whilst the prevailing west winds in winter are attended with violent tempests. In summer whenever the wind changes to the westward it produces fair weather.

From observations during eight years on the north of the sea of Okhotsk, at an establishment of that name, the *wind blows from the southeast and east during the months of June, July, and August, rarely in any other direction, accompanied generally with fogs and rain.* In April, May, and September, the winds are north at night and south in the day, moderate with fair weather. In the latter part of October there are violent tempests from the east and southeast, and when the wind passes to the north or northwest, the fine weather returns.

From December till April, the wind blows constantly from the north or northeast, with a beautiful sky.—(Annales Hydrographique, p. 334.)

23. Captains Galinier and Ferret say that in the month of July, during their travels in Abyssinia, the sun was seen every morning; towards noon the sky was covered with clouds, and the wind from the east or southeast began to blow; towards two o'clock the thunder was heard, the wind increased in force, and the rain fell in torrents; before the setting of the sun, the sky cleared, and the nights were often very fine. During the month of August, this regularity is

already troubled ; it rains then at any hour, and sometimes all day ; at the end of September the rains cease.

24. While the periodic rains fall with violence in Abyssinia, a burning sun darts down his perpendicular rays on the region of Dankali, between the first chain of mountains and the Red Sea, and communicates to this region an insupportable heat. The mountains here spoken of run nearly parallel with the Red Sea, and on the 20th of August our travellers found the temperature at 120° Fahrenheit in the inside of the house at Massawah, on the borders of the Red Sea, which rendered the stay in that town insupportable. The kingdom of Aden, they say, is exposed to nearly the same heat and drought as the region named above. [Caused by the proximity of the rains.]

25. Rev. Az. Smith says, "in a short time after the sun rises, the clouds begin to creep up the north side of the mountains facing the Euxine, and soon afterwards *attaining the summit, they pour over it towards the south, presenting a white sheet along the mountain ridge, not unlike that of the brow of our own Niagara. But hardly do the clouds pass the mountain summits before they begin to melt away and disappear in the arid atmosphere which waits to receive them.* [They do not dissolve in consequence of coming into a dry atmosphere, but by descending and thus coming under greater pressure.]

26. Mr. Miller, in his Meteorology of the Lake District of Cumberland, for 1852, says: "When the mountain is enveloped in mist quite down to its base, particularly if accompanied by deposition, the difference in temperature between the top and bottom does not exceed 7 or 8 degrees ; while under a clear and cloudless sky it amounts to 19 or 20 degrees." [This difference is caused by the latent caloric given out by the condensed vapor.]

Colonel Sabine ascertained on one of the Canary Islands, that when the wind came off the land the dew-point was $37^{\circ}.5$ Fahrenheit, the temperature of the air being at the time 66° . [The Canaries are in the belt of high barometer, where the air descends with its low dew-point.]

27. In the 21st vol., Journal Royal Geog. Society, Mr. W. Bollaert has given an account of southern Peru, with a map of the country from the coast to the higher Andes, between the latitudes of 19° and 22° south. This map shows the courses of a vast many ravines with streams rising in the Andes, and generally losing themselves in the sands below, never reaching the ocean. Speaking of one of these on which the town of Tarapaca is situated, in latitude $19^{\circ} 56'$, $69^{\circ} 35'$ west longitude, he says: "In general there is barely sufficient water in it to irrigate the land in this quebrada as well as in many others ; but when thunder storms with their heavy rains occur in the Andes, great torrents rush down the ravines, bringing with them masses of rock, trees, huts,, cattle, indeed all that may be in their way, leaving, after one of these destructive floods, nothing but a bed of stones."

Hopkins, page 262. "In the latter part of summer, in Italy, I happened once to be standing on one of the small Borromean islands, in Lago Maggiore. The day was fine, rather warm, and perfectly calm. Looking around at the mountain scenery, my attention was arrested by a dark spot being formed in the previously clear atmosphere, which spot enlarged in size rapidly. On directing the attention of a gentleman who was with me to the dark object, he exclaimed: ' Ah! we shall have a storm.' As all around, excepting the small cloud, was clear, this seemed strange. But the cloud rapidly increased in size ; a slight flash of lightening struck out of it ; it grew blacker and spread very quickly, till it covered the whole of that part of the lake where we stood. Rain commenced falling, and soon became a torrent, such as is not often seen in England ;

whilst winds blew in gusts from different quarters. Shortly the storm moderated, less rain fell, the wind died away, and all became fine again. It appeared that the whole had taken place in about a quarter of an hour."

28. In mountainous countries it is known, and has been particularly shown by M. Fournet, in the *Annales de Phys. et de Chim.*, in 1840, that the wind descends the slope of the mountain in the night, and ascends during the day, in the normal state of the weather; but M. Fournet thinks that when these currents are reversed rain follows.

Lieutenant R. Semmes, in his Mexican War, says: "Jalapa, 20° north latitude, has a most agreeable climate. *Its elevation is about 4,500 feet above the level of the sea. It rains constantly after about one o'clock in the day during the rainy season, from June till October, and frequently during the remainder of the year.* The cause of this humidity is very obvious. The sea breeze or southeasterly winds of the Gulf of Mexico, sweeping over the arid plains of the Tierra Caliente, become highly rarified and charged with moisture, and coming here in contact with the mountains, they find their dew-point at about this elevation. Their condensation and dispersion in rain is, of course, the consequence."

Lieutenant Maury, quoting from Dr. Girard, says: "The difference between the dry and wet bulb thermometers on the Red Sea is often 25°, and in the kamsin or desert wind to from 30° to 40°.—(Phys. Geog. of the Seas, page 129.)

29. Vol. 21, page 9. Professor H. Abich, says: "The greatest dryness of the atmosphere anywhere tested by hygrometric observations was found by Humboldt, in the Asiatic steppes of Glatoffskaya, to be 16 per cent. This hygrometric state of the air I have found in my numerous excursions over Armenia to be a very frequent one, but I never observed a greater relative dryness than 17 per cent. in the neighborhood of Ararat. The difference between the dry and wet bulb in the hottest part of the day was frequently 22° to 27° and sometimes 29° Fahrenheit in the shade; and in the summer the prevailing winds were largely from the northeast.

[Becquerel's *Physique et Meteorologie*, page 116.]

30. In Spitzbergen, latitude 77° 30', the members of the scientific committee found, in a series of eight observations made every half hour, that the temperature fell 1° Fahrenheit for 104 yards elevation. Captains Sabine and Foster, however, found a very anomalous result.

On the 17th July, 1823, in seeking to determine the height of a conical mountain of Spitzbergen, between 4½ and 6 P. M., the mean temperature of the air was—

At the lower station..... 2°.88 Fahrenheit.

At the upper station, 548 yards high..... 3°.62 "

It was cloudy, with a gentle wind.

On July 18, between 3½ and 6 P. M., the temperature was—

At the lower station..... 3°.62 Fahrenheit.

At the upper station..... 2°.72 "

On the 20th July, between midnight and 2 A. M., the temperature was—

At the lower station..... 4°.32 Fahrenheit.

At the upper station..... 7°.92 "

On 21st July, between 10½ and 30 minutes after 12, the temperature was—

At the lower station..... 7°.94 Fahrenheit.

At the upper station..... 7°.02 "

In the second observation there was thick fog and light breeze ; in the third the weather was clear and fine ; and in the fourth it was raining below and in the cloud above, so that the anomaly was greatest with a clear sky.

Page 113. Saussure made observations on the top of the Col du Géant (Alps) 3,750 feet high, from hour to hour for 17 days, and also on the Riga, and found the temperature sink on the Riga 1° of Fahrenheit for 81 yards, and on the Col du Géant 1° of Fahrenheit for 100 yards.

31. In McCulloch's Geog. Dictionary, art. Africa, he says : "It is worthy of remark that in Soodan, about latitude 10° north, and at no great distance from the Sahara, *the temperature sometimes descends in the night to the freezing point.*" Also : "It is certain that on the western side of Africa, between 20° and 28° south latitude, a great sandy desert extends over the greatest portion of the table land, in which there falls very little if any rain."

32. Hopkins, on Atmospheric Changes, page 312, quoting from Miller, says : "*The difference in temperature between the valley and the tops of the mountains, in the Lake District of Cumberland, varies greatly, according to the amount of cloud, the presence or the absence of mist on the mountain, and the height of the under surface of the stratus, or cirrostratus, above the valley. When the mountain is enveloped in mist quite down to its base, particularly if accompanied by deposition, the difference in temperature does not exceed 7 or 8 degrees ; while under a clear and cloudless sky, it amounts to 19 or 20 degrees.*"

33. "In 70° north latitude, Messrs. Bravais and Lottin observed that, at an elevation of between 1,312 and 1,640 feet, the temperature rose $10^{\circ}.8$ Fahrenheit.

34. "In the region near the mouth of the Indus, there being no mountains there, the western monsoons of July, August, and September, produce drought."

On the eastern coast of Kamtschatka the prevailing winds are west from the end of September till May, and during the summer they prevail from the east, variable to northeast and southeast. With the west winds variable in the winter there are often violent tempests.

On the opposite coast of America, at New Archangel, latitude $57^{\circ} 3'$, the prevailing winds in the winter are from the east, accompanied with rain and snow. In the island Ounalaschka, latitude $53^{\circ} 52'$, between the coasts of America and Asia, the wind is south 170 days in the year, and southwest 106 days, and south-southwest 41 days.—(Ann. Hydrog., vol. 6, p. 333.)

35. M. A. Quitelet, the illustrious philosopher of Brussels, in his highly interesting work on the climate of Belgium, embodies the following generalizations, which are so valuable that I may be permitted to copy them here entire :

1st. After the experience of eighteen years, there are annually at Brussels 189 days during which more or less water falls, under the form of hail, rain, or snow.

The quantity of water collected during the course of a year amounts to 28.22 inches English.

2d. It rains on 181 days in the year, snows on 25, and hails on 9. In May and April the least quantity of water falls ; in July and August the most falls.* It hails every month in the year, but especially in April and May. In the course of 18 years it did not snow before the 13th of October, nor after the 15th of May.

* It is remarkable that the reverse of this takes place in Soreze, in France ; for there the greatest quantity of rain falls in May and April, and the least in July and August, from a mean of 33 years.—(Annuaire Meteorologique de la France, page 153.)

The barometer, too, at Soreze, was lowest during the two months of greatest rain, and highest during the two months of least rain.

3d. The days on which water falls combine regularly as to their *continuity*; the isolated days are the most numerous, then the combination in twos, next the combination in threes, and so of the rest. The numbers follow a geometrical progression, of which the ratio is 0.635.

In one particular case, water fell more or less for 40 consecutive days.

The same law is observed for days without rain, and the decreasing progression has the same ratio, (0.635.) The longest period without rain, however, is 30 days.

In general, the chances for the days without rain are equal to the chances for the days with rain; but these chances are not independent. There is a tendency, when the rain commences, that it will continue for several consecutive days; and so of the fair weather.

4th. The number of the rains, classed according to their duration—that is, according to the time it rains without intermission—follows also a decreasing geometrical progression, of which the ratio is 0.7. The rains of one hour's duration are more frequent than the rains of two hours; and so of the rest.

The longest time it has rained, without interruption, has not been more than 24 or 25 hours.

In general, it rains more than an hour and a half per day in the summer, and nearly three hours and a half in winter.

5th. As to the number of rains which can fall in a day, we find still a very rapidly decreasing geometrical progression; during the half of the time, there falls but one rain in a day; during the quarter, there fall two; rains more numerous are rare; only once, in nine years, six rains were counted in 24 hours.

6th. It is from noon to 3 P. M. that the rains most frequently commence at every season. However, this law is more distinct for summer than for winter; and it is from midnight to 3 A. M. that the fewest rains commence.

The quantities of rain which fall from six in the morning till six in the evening are greater than during the other twelve hours of the day; the preponderance is very manifest, both for the number and the product.

7th. During winter, the rain raises the normal temperature $3^{\circ}.6$; in the spring, on the contrary, it lowers it a little more than $0^{\circ}.9$, and in the summer a little less; then, in autumn, the temperature is raised about one degree. The rains, in general, produce only a slight elevation of temperature of about $0^{\circ}.77$ Fahrenheit over the annual results. In classing, according to the order of greatness, the departures from a mean, which the temperatures experience during rains, we find that the chances are almost exactly the same for an increase as for a diminution of temperature. The limits of these departures are 18° Fahrenheit on each side of the mean. The hails, the storms, and the hurricanes, are generally preceded by an elevated temperature; the fall of the thermometer follows very generally the commencement of the rain.

8th. The mean barometric column undergoes, during the rains, a depression of about the fifth of an inch, English. This depression varies regularly with the months; its maximum, about one quarter of an inch, is in January, and its minimum, one tenth of an inch, in July. The hour which precedes the rain the barometer more frequently falls than rises; during the rain, its movement is uncertain; it rises more frequently than it falls. After the rain the rise is decided; it rises seven times out of eleven. The instant of the greatest depression is about 40 minutes after the commencement of the rain.

9th. The winds from the southwest, even taking into account their frequency, are those which are accompanied with the most rain; the winds from the northwest and west, in this respect, range next to them, whilst the winds from the east and southeast are the least rainy. As to the quantity of rain per hour, the relations are reversed, the winds from the northeast and north give the most rain per hour; those of south-southwest and northwest give much less than the general mean, which is a little more than 0.03 English inches per hour. The intensity of the wind exercises also an influence; in general, it has rained more frequently, and a greater quantity, during very feeble winds. The quantity, however, per hour is about the same for strong as for feeble winds.

When there is a change of wind at the time of the rains, there appears to be a tendency to change before the rain begins to fall, except in the winter.

[Another generalization would be interesting here—the direction in which the wind changes, and whether it is sudden or gradual, and when gradual, through what points of the compass it changes.—Espy.]

10th. The normal *electricity* of the air during the year is *positive*, varying by degrees very different in strength; the maximum in January is to the minimum in June as 13 to 1.

During snows and fogs the air is always electrized *positively* very strong—generally twice as strong as in January.

The *negative* electricity is rarely observed; it scarcely manifests itself but in rains, or in the neighborhood of rains. In rains it sometimes appears alternately positive and negative; very strong during hard rains and storms; but in tranquil rains it follows nearly the ordinary march.

As to *dynamic* electricity, currents either ascending or descending hardly ever occur but during the rains, or especially the stormy rains. In this latter case, at the appearance of a flash of lightning, a corresponding motion of the needle of the galvanometer takes place, to the right or left, according to the nature of the current.

During the strongest electric tensions the galvanometer may rest in repose and exhibit no current; on the other hand, during the passage of a current, the electrometer may exhibit an electric tension either positive, or negative, or null.

11th. Contrary to the received opinion, the *lunar period* has little influence on the rains; however, the part of the period which follows by some days the first quarter, embracing in it the full moon, and extending some days beyond the last quarter, has given more rain than the remainder of the period.

12th. The results obtained up to the present time show that, in penetrating into the country further from the sea, the quantity of water which falls annually diminishes.

[Annales Hydrographiques, volume 6, pages 223, 315, 323.]

36. In the Indian ocean, the southeast monsoon commences about the middle of April, and the northwest monsoon, variable to west-southwest, commences about the middle of October, acquiring its greatest force in December and January.

In New Guinea, the southeast monsoon blows from the latter part of May till October, and the northwest monsoon from November till May.

In the Straits of Torres, north of New Holland, the northwest monsoon commences about the end of October and continues to the middle of March. The southeast trade blows feebly in April, augmenting in force till June and July, and then diminishes till it terminates.

37. Bad weather never comes on suddenly from the east about Cape Horn, and winds from the south and southwest never change suddenly from the north, but they do suddenly from the north to the southwest and south.—(Page 323.)

[It is well known that in the Atlantic, near the coast of the United States, the wind comes on gradually from the eastward, increasing often to a violent gale, and after a short lull or calm, springs up violent from the westward at once.]

[Annales Hydrographiques, volume 6, page 222.]

38. "In general, the monsoons blow during the summer towards the continents, and in an opposite direction during the winter." [This is the general doctrine taught by the books. The truth is, that the winds, in all parts of the world, blow to the regions of great rains, except on the leeward side of high mountains.]

At the same page it is said on the chart that the wind in the southern part of the channel between Madagascar and Africa blows all the year from the south, and in the northern part of the same channel it blows constantly from the northward from November till April. When the winds which enter the southern part of the channel blow entirely through during the summer of the northern hemisphere, there is no rain; but when these two winds meet, there is great and almost constant rain; and the winds that blow thus towards each other are much more violent than they are during the other season.

[The presumption is, from the great quantity of latent caloric given out by the condensing vapor during the rainy season, that the barometer will be lower also during this season; and if so, it will account for the wind's blowing to the region of low barometer, both from the north and the south in this channel.]

[Annales Hydrographiques, volume 1, pages 351, 353.]

39. In the Gulf of Aden, east of Babelmandel, during the months of July and August, it happens sometimes in the evening, at the moment when the south wind ceases, that a violent squall comes from the land, preceded by a thick cloud of dust, which gives time for the ships to prepare to receive it.

In the Bay of Curia-Muria, on the southern coast of Arabia, a cloud would suddenly appear on the mountains, and the heavens immediately become covered with clouds, and in five minutes we could not see ten metres before us, and at the same time a violent squall blew from the north off land. [These observations were made in the winter.]

[Annales Hydrographiques, volume 2, pages 72, 73.]

40. The squalls (succeeding strong southeast winds) from the mountains which border the eastern coast of the Gulf of Venice are very impetuous. They begin to blow soon after isolated white clouds attach themselves to the mountains of Dalmatia on the coast; nor does this truly terrible wind cease till the clouds are detached from the mountain.

The mariners know, and I am convinced, says M. Tician, that when the clouds come from the west or southwest, the southeast wind will infallibly commence in the Gulf of Venice in two or three days; and when the southeast wind ceases, and the clouds continue from the west or southwest, it is a certain sign the southeast wind will soon reappear.

[Annales Hydrographiques, volume 1, page 365.]

41. The ships which are at Moka (within the entrance of the Red Sea) during the strong winds from the south, which reign in December, January, and February, ought never to try to get

out of the Strait, or they will run great risk of being damaged or lost. They must wait for a lull, and profit by the flow of the tide.

[Annales Hydrographiques, volume 2, page 336.]

42. Squalls from the north are as violent in the Gulf of Honduras as in the Gulf of Mexico, especially in November, December, and January. They occur sometimes, but not so violent, in February and March, and also in September and October. In the Gulf of Mexico they incline to the northwest; in the Gulf of Honduras they have their greatest force from the northwest, commencing with bad weather from the southwest, veering west and northwest, and dying away from the northeast.

Bad weather, with the wind southwest, always indicates them; and there is not a man in the country who cannot announce a norther at least twelve hours in advance.

[Annales Hydrographiques, volume 2, page 429.]

43. On the coast of Algiers the west winds prevail from September to May, and reign almost exclusively in winter. The east wind prevails in the summer. The tempests are from the north at their greatest violence.

[Annales Hydrographiques, volume 5, page 188.]

44. At the Island of Tahiti the trade winds, particularly when they blow from the southeast, are divided by the peninsula of Taiarapu and by the mountains of the centre of Tahiti.

A region of calms of variable size is formed between the northwest wind and the southeast monsoon, extending sometimes considerably over the ocean towards the Isle of Moorea. The season of rains commences about the middle of December and terminates in April or May, and this is the season in which the northwest winds occur, [meeting the southeast trades at the Island of Tahiti.]

[Annales Hydrographiques, volume 5, page 293.]

45. The approach of the pamperos is perfectly indicated by the mass of thick clouds and lightnings in the southwest; a stifling air after a series of winds from the north; by the falling of the barometer; by the myriads of insects driven from the southwest; by hot puffs of air from that quarter; and by the rising of the waters in the La Plata river.

46. Same. The Bay of Kartoli, on the east side of the Gulf of Venice, is less exposed to the violence of the bora, doubtless because of its distance from the high mountains.—(Page 83, volume 2.)

Same. I am convinced that vessels will be exposed to great danger in any part of the basin of the Oriental from the squalls which descend from the steep mountains which surround it on all sides. The wind from the southeast is here also extremely dangerous, and particularly on the north side; there the wind descends from the mountains like the bora.—(Page 85, volume 2.)

[Here it would appear that the wind which comes from the southeast is driven down the southern slope of a mountain, no doubt by violent rain, almost in a direction opposite to the wind above.]

47. At Lé, in Ladak, upwards of 11,000 feet high, the thermometer, on the 4th July, in the sun, rose to 134°, and on the march to Piti it stood ten degrees higher.—(Moocroft's Travels, page 268, volume 1.)

48. In Allen and Thompson's Expedition to the Niger, volume 1, page 73: "In describing

a tornado on the coast of Africa, latitude 13° , longitude 18° , on the morning of June 23d: *There generally appears at first a tumultuous assemblage of clouds in all parts of the heavens; these gradually, as if by concert, hurry towards the east, where they assume their stations, forming by degrees a long, low arch, extending about six points of the compass. In proportion as the lower edge of this becomes defined, and increases in intensity of darkness, so may the near approach of the tornado be expected.*” And then he goes on to describe it as others have done.

49. In latitude 25° north and 10° east, Richardson had the wind south cool on the 1st August. The oasis and mountains of Ghat were to the north about a day's journey.

On the 16th August a violent rain and wind storm about the Tropic of Cancer and 9° east. Many mountains about there. He says, page 221, “there cannot be a doubt that occasionally an immense quantity of rain falls in every region of this great desert.”

50. Maury's Physical Geography of the Seas, page 179: “The rains are found to extend out into the trade winds, and often to a considerable distance both to the north and south of the calm belt.”

The reason of the following fact is, that the barometer below was observed after the rainy season came on; above, it was observed in the dry season.

Alfred R. Wallace says, in the 23d volume of the Journ. Roy. Geog. Society, page 216: “It is a remarkable fact that the pressure of the atmosphere at the mouth of the Rio Negro [six or seven hundred miles above the mouth of the Amazon] is greater than at the mouth itself—at Para.”

51. During the expedition undertaken by General Cavaignac on the 1st of April, 1847, in the Algerian Sahara, in the midst of this sea of sand the troops had to bear atmospheric vicissitudes which were surprising in this season and under this latitude. The thermometer in the shade rose sometimes above 104° of Fahrenheit, and soon afterwards, if the sky was covered with fog, it sunk to the freezing point, and in the night was seven degrees below.

What was the astonishment of the troops, on the 19th April, when they saw, in the morning, the vast extent of the desert, as far as the eye could reach, covered with a thick stratum of snow. The soldiers benumbed with cold, and overtaken by that perfidious drowsiness, the precursor of death, which could hardly be overcome by the exhortations of the officers, the noise of drums, and the sounding of clarions.—(Foissac, volume 2, page 264.)

At sea, says Koemtze, in the region of the trade winds, storms appear to be as rare as rain, for I do not recollect to have found in any voyager an account of a storm of any violence in that zone.—(Foissac, volume 1, page 159.)

WILKES' THEORY OF THE WINDS.

52. Near the Cape (Horn) fine weather accompanies the fall of the barometer, and a gale is seldom felt till it begins to rise, when the wind veers several points, and increases till it blows with great violence. This continues till the mercury has attained its ordinary height.—(Page 67.)

The wind in these storms comes from the frigid zone. The same rise of the barometer takes place in the far north during storms, with the wind from the north, coming down underneath an upper current, moving in the opposite direction.

"At Valparaiso, about latitude 32° south, the northers are indicated by a fall of the barometer with a day or two of dull heavy weather, and an increasing swell setting into the bay. The immediate precursors of them are a lighting up of the clouds, and a bright, clear sky to the northward and westward, and the looming of the land to the northward off Concon and Quintera, which is not usually visible from the bay."—(Page 70.)

The probability here, I think, is, that the storm cloud moves towards the southeast, and when the centre of it passes the harbor, the spectator can see under its northwestern edge, and then soon the wind will begin to blow towards the centre of the cloud just passed; that is, the wind will come out suddenly from the northwest, following the cloud.

In passing from Callao, in July, to the Paumotu group, Captain Wilkes "sometimes observed the scud flying rapidly from the southwest, and the effect of a southwest wind was evident by the interruptions and long swell from that quarter. The sky was unattended with the light clouds that are met with in the trade winds. In the Paumotu group the trade winds in the winter season were by no means regular, (though this group is within the torrid zone.) The winds are often from the southwest. The weather is frequently very unpleasant, inclining to calms and light winds, with an occasional squall. It is, however, the fine season, for in summer, gales from the west not unfrequently occur, blowing very heavy with rain."—(Pages 72 and 73.)

"Easterly winds prevail to the southward of latitude 60° south; but to the north of that parallel westerly winds, accompanied by fog, snow, sleet, but seldom rain. *Heavy cumulus clouds in the southwest indicate wind from that quarter, as they do to the south of Cape Horn*; but though boisterous, they are not to be classed as storms. *The barometer ranges low, the mean being 29.04 inches*; its movements are rapid. The wind increases as it rises and continues for some hours after it has become stationary."—(Page 87.)

53. Lieutenant Gibbon says that "the wind is constantly east at Lake Titicaca, between the Andes and Cordilleras, in about latitude 16° south, and that it is constantly cloudy even in the dry season, except sometimes in the night when the wind blows from the west.

"The lake in November had a temperature of 64° though the temperature of the air seldom rose to 60° in the day, and at night was generally much lower. Persons have seen hundreds of waterspouts standing on the lake at one time, as though the columns were supporting the weight of the clouds. The Indian balsas or canoes are made of rushes, yet the falling of one of these waterspouts only washes the dust off the Indians as they pass through this wonderful phenomenon. We are nearly suffocated at times with the dust whirling up all round us."

The force of these waterspouts, as the author here describes them, is very feeble, and it therefore seems probable that they are merely small columns of air taking their rise from the comparatively warm surface of the lake, and being nearly saturated with vapor, or quite so, the condensation of this vapor from the cold of diminished pressure, as the air ascends, will exhibit them as inverted cones of cloud, touching with their apexes the surface of the lake. If this is the true explanation of the phenomenon, it is probable it will be discovered by future observers that these pillars of condensed vapor are only seen when the air over the lake is nearly calm, with the exception of the wind in the borders of the pillars themselves, and that the washing of the dust from the balsas of the Indians is either the rain coming down on the outside of the pillars, or the air going up in the inside.

It appears, also, both from Lieutenant Gibbon's and Lieutenant Herndon's observations in

their journey across South America, from the Andes to the mouth of the Amazon, that the wind blows almost constantly from the eastward, though much stronger in the day than in the night. The wind is stronger in the day than in the night everywhere; because, in the day, the up-moving columns of air let down the air from the upper regions, which continues its motion all night; whereas in the night there being no up-moving columns, the air at the surface of the earth soon diminishes in velocity by friction on the earth's surface. And Lieutenant Herndon says, in his journal of the weather, that *there are always heavy clouds and rain where a range of hills rises above the plain. The Indians speak of "Cerros mui bravos," to indicate the fierceness of the weather about them.*

Lieutenant Gibbon says that "the heights of the eastern side of the Andes are among the most terrific portions of the earth. *They seem to correspond to the rocky shores of the ocean when the waves beat heavily against their banks. The trees, bushes, vines, creepers, and mosses are heaped up just here like we find the sea-weed hanging on the rocks of the seacoast.* Nor do all the easterly winds that strike the broadside of the Andes glide upwards; but the current is sometimes divided, so that in the heavy gales which sometimes blow in the rainy season from the eastward, with such force as to uproot the trees, the lower half turns under, sweeping down over the forests with such force back towards the east as to break down the trees with their tops towards the east." [Is not this backward motion of the air below produced by the weight and cooling effect of the rain and hail on the lower part of the air, as explained in No. 150? Lieut. Gibbon thinks it the rebounding of the air in part which strikes against the side of the mountain. If it shall be found, by future observers, that the air ever blows back towards the east from the base of the mountain, while it blows strongly from the east above *without rain or hail*, then will my explanation be incorrect.]

54. Von Froil, who visited Iceland with Sir Joseph Banks, says that "lightning and thunder storms are rare, and both in summer and winter seldom happen anywhere in Iceland but in the neighborhood of volcanoes." The last time Katllegiaa emitted fire, a flash of lightning burst from the flame and killed eleven horses. A farmer was killed near the door of his room; his upper clothes, which were of woollen, remained unhurt; but his shirt and waistcoat, which were of linen, were burnt.

"First, I hesitated to believe this as true, but when I read that Baccini had observed, in 1631, that a column of smoke from Vesuvius extended over several miles of the country, from which deadly lightning proceeded, and that the same happened in 1769, when the iron rods erected in Naples became electric whenever Vesuvius emitted fire, I am more inclined to believe there is something electrical in this kind of fire."

55. Edmund Roberts, in his embassy to the east, says, that the wind at Macao and Canton is from the N.E.N. and N.W., from October to March, and from April to September the wind is southerly and southeasterly. (Page 162.)

Erman says, in his Travels in Siberia, vol. 2, page 169, "What the south winds are to Irkutsk, the north winds are to Canton. They begin in October, and are attended with great aridity, [blowing both ways from the belt of high barometer.]

56. Erman, in 2d vol., page 532, says: "I was here almost compelled to assume that the atmospheric pressure on the sea of Okhotsk is no greater than it is in the middle of Europe, at the height of 350 feet." [This is in the northern belt of low barometer.]

57. Hooker, vol. 2, page 60, found the river Zemu, in the Himalaya, increase in temperature as he ascended in summer. In going up from its junction with the Thlonok 1,100 feet, it rose from 46° to 48° , and 1,100 feet higher it was 49° . [Produced by the evaporation as the dry air which runs down the river valley.] (This was on the north of the southern range.)

Here the clouds prevent alike the solar and nocturnal radiation, the temperature is more uniform, and the damp southerly wind that blows strongly throughout the day is the great melting agent; therefore the rivers have no diurnal rise, as the Swiss rivers have. (Page 68.)

58. A. G. Findlay, in the 23d vol. of the Jour. Roy. Geog. Soc. has shown that there is a current in the Pacific ocean running from the west to the east, in the calms a little north of the equator. [This current is many thousand miles long.]

59. Dr. Arch. Smith, vol. 2 page 2, "Cero Pasco is situated between eastern and western Cordilleras 14,000 feet high. Its climate for nearly one half the year, from the end of November to May, is exceedingly gloomy and variable. In the course of a few hours the wind is often observed to take the round of the compass; and in the same time it changes from fair to rain, from rain to sleet, snow, hail and rain again. The lanes (for streets they merit not to be termed) are, during the greater part of these months, wet and miry. The thermometer of Fahrenheit, during this period, rarely rises above 40° in the shade, and seldom falls so low as the freezing point. But during the dry season, which reigns from May to November, it is much otherwise; and then, though the sun at noon shines forth with great power in the face of a cloudless canopy, the frosts at night are intense, and the evenings and the mornings are keenly piercing and cold. In the course of the month of August, *the air is so remarkably dry that the nose and face become parched and painful. The writer suffered so much from this troublesome affection as to find it necessary to seek a more temperate air a few leagues off, when the ailment disappeared immediately.*" [The time that the belt of high barometer is over that region.]

60. "At the time of the last eruption of Mount Idienne, a volcano in the east of the island of Java, so great a body of water was forced out that the country extending from the mountain to the sea, a distance of 20 leagues, was inundated, and it gave rise to two large rivers." (Edinburgh Phil. Journal, vol. 30, page 85.) [Was not this water from meteoric rivers?]

61. Professor Plantamour says: "The same atmospheric wave produces the maxima and minima of the barometer at Geneva, and at St. Bernard, to the southeast of Geneva; but these take place later at St. Bernard than at Geneva, from 2 to 32 hours, in the year 1852."

62. Commander R. McClure says: "The winds prevailed from N.E. to E.S.E. on the northern coast of Russian America." (Discovery of the Northwestern Passage.) [Winds blowing towards the belt of low barometer.]

63. Researches by Mr. Liais on the temperature of space, 97° , the top of the atmosphere about 100° , constructing the curve of decrease of temperature with the diminution of pressure (not heights) for abscissas, and the temperature for ordinates.

Mr. Liais thinks the heat received from the stars is insensible. (Committee Arago Pouillet Regnault.)

[Thomson's Himalaya and Tibet, page 484.]

64. "In the most western part of the Himalaya, in Kashmim and Balti, the winter's fall of snow commences about the beginning of December, and continues on the highest ranges nearly to the beginning of May. The supply of moisture, from which the snow is condensed, is

evidently derived from the Indian seas, and I suppose principally from the southwest, that being the direction from which I observed storms to arrive at Iskardo."

[Annales Hydrographiques, volume 2, page 254.]

65. "The wind near the coast of Morocco blows generally from the northeast during nine months of the year, with fair weather, which the inhabitants call a regular trade wind; the south winds, during December, January, and February, are subject to tempests." [The belt of high barometer passes north and south of this locality every year.]

66. Lain, in his *Residence in Norway*, page 302, says: "The western part of Norway, especially about Bergen, and along the coast, is proverbially rainy, owing to the high mountains which collect the clouds driven from the sea. But the country behind this barrier is, on that account, particularly dry, perhaps rather too much so."

67. Colonel Reid, page 75, quoting from Captain Newbold, says: "It is well known that where the Ghauts attain a certain height, neither the northeast nor southwest monsoons usually ascend above them."

Captain Newbold further says: "I was, on the 24th of October, 1842, crossing the eastern Ghauts at the time of the storm at Madras, a little south of the latitude of Nellore, (nearly west of Madras,) and observed an enormous mass of irregular clouds rise from the eastward and advance regularly on the mountain. Here the great bulk was arrested, and collected in a long horizontal wall-like bank, of solid aspect, and of deep bluish hue, varied at the edges by flocculent curves and zones of sombre gray, which appeared in vivid distinctness, as corruscations of lightning shot up and illuminated portions of the gloomy mass. In height and contour, they resembled the mural barrier opposed to them. They remained in this sullen form, apparently motionless, for a day or two, when they gradually dispersed.

"There was little wind in the sheltered valley along which I passed, and that little variable. A few detached higher clouds escaped and passed slowly to the westward, whilst portions of the upper edge of the cloud bank would sometimes curl over the top of the ridge, like the falling crest of a wave dispersing in spray, and descend, in a transient shower, on the western slopes. An almost similar phenomenon is presented on the table lands on the west flank of these same Ghauts, on the commencement of the northeastern monsoon." [There is no doubt the wind goes over the top of the Ghauts, and swims on the top of the air on the other side, for it rushes over the Himalaya with great violence.]

68. Colonel Reid, page 144, quotes from H. Piddington the observations which he made in Calcutta at the time the centre of a very violent hurricane was over that city and previous to its arrival, which, when carefully examined, prove to be very instructive.

"During the latter part of May, 1842, the weather was excessively close and oppressive, particularly during the nights. It was on the 27th that we had the first northwester, after which the weather was calm.

"1st June. At 6 A. M. the barometer had fallen from 29.625, at which it had previously been, (the usual average of May being about 29.72,) to 29.465. The wind was E.N.E., in variable puffs, rising from heavy nimbi and cumuli to the east, flying fast from about due east to west. Clear and rather dark blue sky, with light strata above the scud. Cloudy and squally through the day. The scud not remarkable in the afternoon, but always coming from the east and southeast; a thick bank hanging to the eastward.

"2d June. After midnight, squally from the east, with rain. Daylight, heavy and rapid scud from the northeast; wind rising and falling. Barometer, at 5.30 A. M., 29.355.

* * * "At 10 A. M., wind northeast by north; strong squalls; barometer 29.355. Noon, barometer 29.355; strong northeast gale; rapid white scud, with breaks of dark blue sky and masses of white cumuli. 2 P. M., squalls at intervals, barometer 29.265. Calms and squalls at 7 P. M., barometer 29.245; light puffs and calms till 10 P. M.; and towards midnight barometer about 29.17. Squalls increasing from northeast.

"3d June. By 7 A. M. heavy squalls and rain from northeast. At 5 A. M. barometer 29.065; thermometer 84°. Hard gale with heavy squalls; scud rapidly flying from the N.N.E. and N.E. by N.

		Barometer.
" At 6 ^h 15 ^m A. M.	Heavy gusts about N.N.E.....	29.075
8 0 "	N.E. by N.....	29.035
8 45 "	N.E. by N.....	29.015
9 15 "	N.E. by N.....	28.995
10 0 "	N.E. by N.....	28.905
10 30 "	N.E. by N.....	28.865
11 0 "	N. by E. Thermometer 83°.....	28.735
11 30 "	N. by E.....	28.715
11 45 "	N. by E.....	28.675
Noon.	N.N.E.....	28.625
0 35 P. M.	N.E. by N. and N.N.E.; tremendous hurricane gusts.....	28.475
1 5 "	N.E. by N.; very heavy squalls at longer intervals.....	28.37
1 30 "	At times almost calm, with moderate breezes.....	*28.535
1 45 "	Calm	
2 0 "	Calm	28.315
2 30 "	Calm. Scud indistinct, but, if driving at all, from E.N.E. to W.S.W	28.285
3 0 "	Calm. Scud from E., but very slow and indistinct; a very light from E. with drizzling rain	28.275
"At this time I drove out on the esplanade. The appearance of the sky was very remarkable. In the zenith the direction of the scud could not be determined, the haze was so thick; but to the east and northeast it was slowly moving, as before, to the west and southwest, while in the south, from thick heavy masses of clouds the scud was rising and flying to the north and northeast.		
" At 3 30 P. M.	A light squall and drizzling rain about S.W.....	28.275
4 30 "	Breeze from S.W. increasing fast, (the scud having begun to move from S. about 3.20,) with squalls and drizzling rain from the S.W.....	28.285
5 0 "	Heavy gusts from S.S.W; to S.W.; scud as rapid from S.W. as before from N.E.....	28.320
5 30 "	Tremendous gusts from S.W.....	28.385
6 0 "	.....	28.525
6 30 "	Terrific	28.580

* Probably a mistake, and should be 28.335.

"At 7 ^h 0 ^m P. M.	Terrific	28.65
7 30 "	Very heavy, but more moderate between the gusts	28.710
8 0 "	Heavy gust again S.W.....	28.755
8 30 "	Heavy gust again S.W.....	28.815
9 0 "	Heavy gust, but more moderate in the intervals.....	28.850
9 30 "	Moderating, but with sudden and severe gusts	28.895
10 0 "	Sudden gusts.....	28.925
10 30 "	Sudden wind, perhaps S.S.W.....	28.985
10 45 "	Sudden still, with severe gusts.....	28.995
11 50 "	Sudden	29.00
2 0 A. M.	4th June. Moderating, but still strong gales S.W	29.015
4 0 "	Strong monsoon gale.....	29.045
6 10 "	Strong breezes, but at moderate intervals nearly calm.....	29.105
10 20 "	Calm, with breezes at times from the S.W.....	29.215

"From this time till Sunday the barometer was slowly rising to about 29.38, with, at times, a variable 'monsoon gale' from S.W., with intervals of calm, and at others blowing hard in squalls, with rain."

This journal, highly interesting of itself, is rendered doubly so by the following "Extract of a letter from Captain Buckton, commanding the brig *Algerine*, to Mr. Piddington:"

Algerine. "On the 28th of May, 1842, in latitude 10° N., longitude 92° 26' E., (about S.S.E. of Calcutta, near 1,000 miles distant,) the sky became a perfect dense mass of clouds, with the scud flying rapidly past from N.E., S.E., and W.S.W., the wind light and sea rising in bubbles as if the wind was blowing from every point of the compass, hissing and rising up in bubbles like a boiling cauldron. Here the barometer fell to 28.60. This being excessively low for so low a latitude, induced us to make every preparation for severe weather. From this time until the 1st of June, latitude 15° 25' N., longitude 87° 58' E., (about S.S.W. from Calcutta, near 500 miles,) experienced an increasing gale, steady from the S.S.W. to S.W. by W., with much lightning and heavy appearance all round. The barometer rising and falling according to the strength of the squalls, or the preponderance of rain, from 28.70 to 28.56. On the 2d, civil time, the gale increased so as to oblige us to lay to, the barometer having fallen to 28.45, latitude 17° 20' N., longitude 87° 6' E. At 9 A. M. we experienced a cross sea setting in from the S.W., N.W., and N.E., the former preponderating; the rain pouring down in torrents, and squalls blowing in fearful violence from the W.S.W., shifting suddenly from that to N.W., to N.N.W., and as far as N., the barometer gradually falling until it came down to 28.18.

"At midnight, more moderate; barometer up to 28.36; steady gale from S.W. by W., decreasing towards noon.

"At 3 P. M., when in latitude 19° 10', longitude 86° 42', enabled to make sail until 11.30 P. M. of Friday, when the barometer again fell to 28.20 during a most severe squall from the N.W. False Point was then bearing N.W. twelve miles. Here we were obliged to stand to the S.E. for two hours, when we again made sail, and on the following night we were anchored off the tail of Sauger Sand."

69. "The most annoying visitor of the regions around is the sirocco or southeaster. This debilita-

ting breeze—the dreaded *samiel* of Egypt, sweeping over the parched deserts of Arabia and Africa, where the hottest summer climate in the world is to be found—is moderated by its passage over the sea, to a tolerable degree of temperature, and on the east coast of Sicily, where it first arrives, its effects are inconsiderable; but seeming to acquire additional heat in its progress over the land, it becomes a serious inconvenience as it advances. At its commencement, the air is dense and hazy, with long white clouds settling a little below the summits of the mountains; it often terminates by a rapid lull, which is succeeded by northwest breeze.

“This wind is peculiarly disagreeable at Palermo, although situated in the northwest part of Sicily; *but the plain is surrounded on the land side by mountains*, which collect the solar rays as if to a focus.”—(Smyth’s *Mediterranean*, page 251.)

[It seems quite certain from this account that, during the *sirocco* at Palermo, there is rain on the east side of the mountains, and that the great heat at Palermo is caused by the latent caloric given out by the condensation of the vapor into the air crossing the mountains and coming down upon the town with the heat in it, and if so, it does not depend at all for its heat on the hot plains of Arabia and Africa.—See 194.]

“The coming on of the *bora* may, fortunately, be known some hours beforehand, by a dense dark cloud on the horizon with light fleecy clouds above it, a rather lurid sky, and it is immediately preceded by a breathless but speaking stillness. In general, its source is between north and northwest, and its usual continuance about fifteen or twenty hours, with heavy squalls and thunder, lightning, and rain at intervals.

“These *boras*, however, give sufficient notice of their approach to an attentive observer; though *borinos*, or strong squalls, from the same quarter, of short duration, may sometimes be encountered without much barometrical indication. A very hard summer *bora* occurred in Lissa harbor, on the 13th of July, 1819, with a fall of the barometer from 30.15 inches to 29.77. It was precursed by the *usual denseness near the horizon, with a fresh southeast wind*; and during the two preceding nights, although the weather was fine, there was much lightning in the vast cloud bank which had formed. On the third evening this bank spread over the sky to the zenith, and the corruscations became incessant. In the midst of this aerial tumult, at about one in the morning, the gale suddenly chopped from south-southeast, to north-northeast, with such fury as to make the ship keel over in an extraordinary degree.—(See 196 and 150.)

“On the ninth of August, we experienced a *bora* of short duration, but of tremendous violence. In the morning the wind was southwest, the clouds lurid, and the whole celestial aspect singular and threatening. In the afternoon the horizon, from northwest to north, was as black as possible, and the gloominess of its appearance was contrasted by a bed of white fleecy clouds which rose immediately above it, and soared rapidly till they joined a series of waved distinct streaks overhead, forming an immense arch from west-southwest to east-northeast, with a deep blue sky on each side. In a few minutes a strong wind had evidently arisen in the northwest, as it blew the clouds right and left, though we felt the southwester stronger than in the morning. At length, after a momentary stillness, huge drops of rain plashed down, and the whole atmosphere seemed to resolve itself into black smoke, while the north wind was seen approaching by the eddies of sand which it threw up before it.

“The gust now reached the ship, roaring tremendously, with such force that both our cables were snapped like twine. The rain poured down a deluge, and every boat in the port was

either swamped or capsized. The excess of violence lasted only a few minutes, and in less than an hour all was restored to comparative tranquillity."—(See 196. Admiral Smyth's Mediterranean, page 257.)

From this account it is certain that the bora is produced by the weight of the rain and its cooling effect on the air, as explained in 150 and 196.

70. "When a northerly wind blows through the strait between Sicily and Italy, and meets a southerly one some twenty miles below it, it is the occasion of much aerial commotion.

"Another singularity is, a calm in the strait, with masses of superimpending clouds, though blowing fresh outside."—(Smyth's Mediterranean, page 250.)

"The south wind seldom blows on the coasts of Andalusia and Granada; but a singular change is known to occur here; for frequently in arriving at the coast abutment, [like our Cape Hatteras] called Cape San Martino, which divides Mercia from Valencia, a ship running free before a westerly wind *there* encounters another from the north or northeast, often blowing fresh."—(Smyth's Mediterranean, page 239.)

"In those bays which bound the ravines and valleys of the higher grounds, the land squalls are violent, though not of very extensive action; for I have felt these descending *easterly* gusts inshore, though the *breeze was fresh from the southwest*, in the offing of the Gulf of Gioga; and standing with this into the Faro of Messina, have there met with a steady southeast wind. The notable mountain storms of Calabria commence with massy clouds coursing, displacing, and effacing each other like oceanic waves, in rapid grandeur; the tempest then rages, but its energy is soon exhausted."—(Smyth's Mediterranean, page 247.)

"The *mistral* is a chilly searching northerly wind, which, after passing the high Alps and their extensive snows, takes its course with increasing violence towards the warm atmosphere of the Mediterranean, and is very impetuous in coming down the valley of the Rhone."—(Smyth's Mediterranean, page 245.)

In the Bulletin of the Geog. Society at Paris, vol. 4, for the year 1845, pages 282 to 285, it is said, quoting from M. Middenoff, that "on the coast of the sea of Okhotsk, about latitude 55° , the diluvial rains, which continue the whole summer, succeed the region's cold of winter, and precede the fogs of autumn. In the month of July there were but eight days without rain. And what is very remarkable, the south side of the mountain Stanoroi is much colder than the north." [These rains cause the low barometer there, from the latent heat evolved.]

71. It seems probable, from the following facts, extracted from Orlando Whistlecraft's Climate of England, that thunder storms in England also travel from north of west to south of east:

Page 2. In summer, too, a southeast wind always prevails in the eastern counties before the great thunder storms, which by night spread themselves over the greatest part of England. These storms are evidently aided in their rise and progress, or passage to the eastward, by a southwest or west wind behind them, which combats against the sea breezes so usual in Kent, Essex, Suffolk, &c., from southeast or east during hot days.

Page 7. The southeast wind blows in July with the hottest and clearest days for nearly a week in the eastern counties, until vapors arise with a southwest current and form distant ranges of rocky clouds in the southwest horizon. These, and the white and round detachments of cirrocumulus in trains across the zenith, are the first clouds after clear and hot days indicating a change, which takes place by the southwestern clouds coming on with a severe thunder storm,

by night for many hours, while the wind continues east or southeast, until it passes, when it veers to the southwest, whence the storm arose.

Page 10. On the night of the 9th August, 1787, a dreadful thunder storm came on. This was introduced by a fine and hot week, with easterly wind, and the storm came on as usual from southwest, whither the wind afterwards veered.

Page 22. In a hot and clear sunshine so much moisture is drawn up by evaporation that many distinct cumuli are formed by 10 A. M. in the otherwise clear sky. These increase in size till about 2 P. M., after which they decrease, and at sunset we have none again in view.

Page 27. The cumulus is truly the day cloud, beginning to form itself in a previously clear morning, increasing till 2 P. M., and then decreasing, until at sunset no cloud again appears. In this case we see a mere speck of vapor, at about 10 A. M. in a summer's day, accumulating till a semi-circular body is formed, having a flat base, while the upper part is somewhat rocky in appearance.

Page 28. As the cumulus is about to pass into the nimbus, the middle of the cloud will represent the neck of a mushroom, and the summit spreads and overhangs the base in a most striking manner, and the tops of these clouds may be compared to the ebullition or, at least, to the effervescing of some fluid.

Page 30. It has been long observed by meteorologists that a southeast wind (in the eastern counties at least) precedes the most violent thunder storms, and that the storm itself works its way in a higher current from the westward.

Page 67. On the 23d May, 1830, an extraordinary cloud began to rise at 6 P. M., and veiled the southwest in blackest hue for two hours. It made its way against the opposing current below, with a continued blaze of blue lightning, and continued over us about an hour. And on the third of June, at 4 P. M., a violent storm came up against the lower current, which was east-northeast. On the 26th June, 1833, a thunder storm came from the southwest, wind north-east. The same phenomenon occurred on the 24th August, 1834, and also on the 13th October, 1836, and 29th June, 1838.

CLINTON HOTEL, NEW YORK, *December 20, 1839.*

72. DEAR SIR: Understanding you are desirous of collecting curious meteorological facts, I take the liberty of communicating to you what I saw in the month of December, 1815, at the island of Owyhee. I lay at that island in the Cavrico bay, in which Captain Cook was killed, three weeks, and every day during that time, very soon after the sea breeze set in, say about nine o'clock, a cloud began to form around the lofty conical mountain in that island, in the form of a ring, as the wooden horizon surrounds the terrestrial artificial globe, and it soon began to rain in torrents, and continued through the day. In the evening the sea breeze died away and the rain ceased, and the cloud soon disappeared, and it remained entirely clear till after the sea breeze set in next morning. The land breeze prevailed during the night, and was so cool as to render fires pleasant to the natives, which I observed they constantly kindled in the evening. I was particularly struck with the phenomena of the cloud surrounding the mountain, when none was ever seen in any other part of the sky, and none there till after the sea breeze set in, in the morning, which it did with wonderful regularity. The mountain stood in bold relief, and its top could always be seen from where the ship lay, above the cloud, even when it was the densest and blackest, with the lightning flashing and the thunder rolling, as it did every day. I passed up through the cloud once, and I know, therefore, how violently it

rains, especially at the lower side of the cloud. This rain never extends beyond the base of the mountain; and all around the horizon there is eternally a cloudless sky. The dews, however, are very heavy, and there seems to be no suffering for want of rain. That this state of things continues all the year, I have no doubt, from what an American, by name of Sears, who had spent four years there, told me; he said he had seen no change in regard to the rain.

CALEB WILLIAMS,
Of Providence, Rhode Island.

Professor ESPY.

JANUARY 2, 1840.

Having read the above, I can safely attest to the truth of what Mr. Caleb Williams writes; but, furthermore, can say it is the same on all the mountains on the different islands of the group.

JOSEPH STEEL, *of Boston.*

PROFESSOR LOOMIS' STORM.

73. On the morning of the 18th December, 1836, says Professor Loomis, the barometer was at an unusual height along the line of the Mississippi river, while in the eastern States it was quite low, but rapidly rising; and the wind east of Detroit was then very uniformly blowing from the west. In the valley of the Mississippi the barometer was at its maximum, and the winds consequently were light, and their directions various. There was a barometric minimum at this time not far to the west, towards which the whole [lower?] atmosphere soon precipitated itself with great violence.

The barometric maximum travelled easterly, and on the morning of the 20th it passed through the eastern extremity of Maine. The barometric minimum now coincides nearly with the bed of the Mississippi river. On the west of this line the wind blows from the north and northwest; on the east side it blows from the east and southeast and south. The winds in this direction blow with great strength.

On the morning of the 21st, the barometric minimum had arrived nearly at the city of New York. In all the middle and western States the wind is from the west and northwest. At a few places it is north, and at a few others southwest; and on the east side of the barometric minimum the prevalent direction is from the southeast. In the line of the minimum itself, which extends from Florida to Quebec, [and probably twice as far,] the mean direction of the wind, which was very strong, was about south 5° east. At a certain distance, however, from the line of minimum, the courses are very uniformly southeast. In the afternoon of the 21st, the line of minimum had nearly reached Boston, and the northwest wind had become the prevalent one throughout almost the entire United States. In the extreme west, the wind had begun to moderate its violence, and at Fort Jesup it was northeast, and at Fort Gibson east, and at Jefferson Barracks southeast. On the 22d, the northwest wind was almost everywhere the prevalent one, particularly in the eastern States, where it blew invariably from some point between the north and southwest. On the southern border it blew very uniformly from the north, and in the western States the winds were becoming light and irregular, veering round to the south and southeast as they had done three days before.

At the rate with which the storm moved across the western States, it would have travelled from the Rocky Mountains to Fort Leavenworth in sixteen hours. And Professor Loomis says

there can be no reason seen why the storm should not have extended to the Rocky Mountains. But he thinks "it could not have come from beyond them; for even if a warm moist current should blow across those mountains, it would be a cold dry air when it descended on the other side."

So far, then, as rain is concerned, the Rocky Mountains must be supposed the western boundary of the storm.

"I am unable," says the professor, "even to conjecture the probable limit of the storm on the north. The oscillation of the barometer increased pretty uniformly from the most southern station [latitude 20°] to the most northern, [Quebec.] Why should not the storm have extended as far to the north as it did to the south of this station? On this supposition the northern limit would be near the arctic circle. At a little distance from the line of barometric minimum, on the east, the wind was from the southeast, while on the west it blew from the northwest. These were both violent winds, probably not less than forty miles an hour. But how is it possible for low winds, not far separated from each other, to blow violently towards each other for hours, and even days, in succession?"

The professor here endeavors, at some length, to prove that the southeast wind ascended from the surface of the earth, while the northwest wind flowed under it; and that the southeast wind, on ascending, divided, part going to the southeast and part to the northwest. The cause of the commencement of the southeast wind was the fact that the greatest depression of the barometer was at some point north of the United States. The chief cause of the depression of the barometer, he says, was this: "The southeast wind, which accompanied the rain, moved with an accelerated velocity. The particles, therefore, of air at one extremity of the current must have left those of the other extremity at an increased distance. Hence, a mechanical rarefaction, and, of course, diminished pressure, near the central line of greatest depression; part of the depression, he thinks, is due to the upward motion of the air." With great respect for the opinion of the author of this very able and most important paper, I dissent entirely from the views here expressed as to the causes of the barometric depression. There is but one cause of the *great* barometric fluctuations—the change of weight of the whole column of air from the surface of the earth to the surface of the atmosphere; and this weight can be affected to any considerable extent only by heat, sensibly, however, by moisture. The professor thinks "it cannot depend principally on heat, for the barometer sometimes falls as the temperature of the air diminishes." But if the doctrine everywhere taught in this book is correct, the upper regions of the air at this very time are in temperature greatly above the mean, containing the latent caloric of vapor recently condensed in a neighboring storm of rain or snow. An up-moving current of air is a *proof* that the barometer is depressed where it exists below what it is in the borders of the up-moving column, but it is not the *cause* of that depression. On the contrary, if the air were forced in on all sides by mechanical means, by impulsion and not by aspiration, towards a central space, it would *ascend* over that space, and at the same time the barometer would *rise*; and the laws of spouting fluids teach us that the rise of the barometer would be in proportion to the square of the velocity of the ascending air. Indeed, there is no conceivable way of preventing an accumulation of air over a space towards which the air below blows, and thus a rise of the barometer under the ascending column or current, but by supposing an outward motion of the air above; and this is true in all cases where the motion of the

air is inward below, even if there should be a gyration or whirlwind there. Now, as the barometer stands low in the middle of all storms, it follows that the air must run out above as fast as it runs in below; and if Professor Loomis will calculate the expansion of the air in the cloud, due to the evolution of the caloric of elasticity and caloric of fluidity, during the condensation of vapor which formed the cloud, he will find it adequate to produce the effect in question without calling in the aid of any other causes. It is not the acceleration of the air below, towards the centre of the storm, which causes the barometer to stand low there; it is the outspreading of the air above which is the cause, both of the fall of the barometer and of the inward motion of the air below. In the case of tornadoes, it has been supposed that the outward motion of the air above was produced by the centrifugal force of a mighty whirlwind in those lofty regions; and Mr. Osler, finding there was no whirl below, applied that conjecture to the great Liverpool storm of the 6th and 7th of January, 1839; but since that storm, as well as this, was of immense and unknown length from north-northeast to south-southwest, this conjecture cannot be true; and therefore it seems probable, from this fact alone, that it is not true in case of tornadoes.

Besides, it is altogether unphilosophical to suppose a whirlwind above, without showing some possible way in which that whirlwind could be produced, which I think never can be done. Professor Loomis has not attempted to show that the cause which I assign for the fall of the barometer in storms is inadequate to produce the effect, though he clearly shows that not one of the causes which others have assigned can account for the phenomenon.

If the cause, however, which he assigns is the true one, it was unnecessary to mention mine, for the establishment of one is the refutation of the other. But the professor also thinks that "part of the depression is due to the upward motion of the air."

To this proposition I cannot assent.

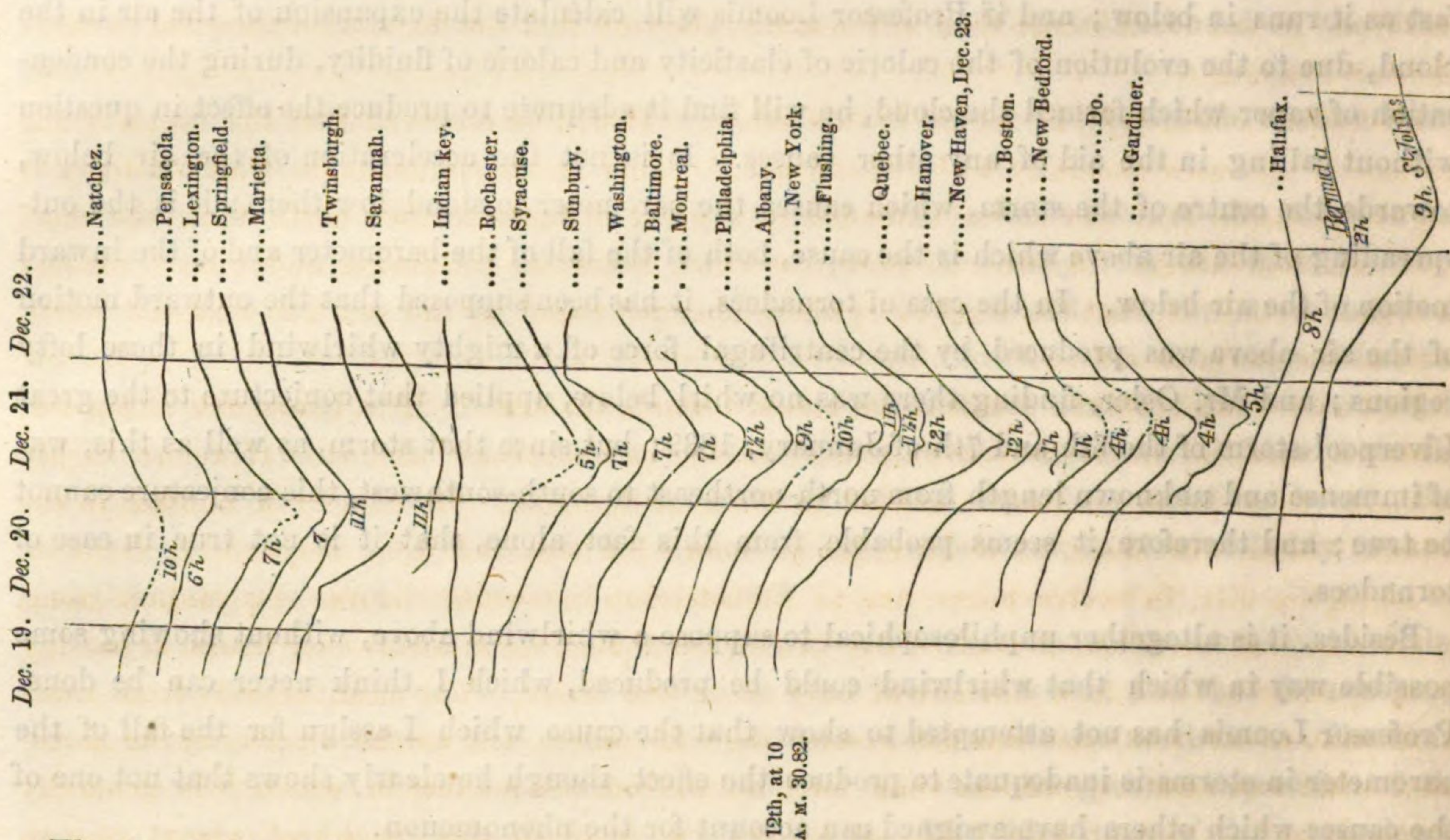
Let the reader imagine one barometer in the inside of a storm cloud near the top, ten miles from the surface of the earth, and another at the same elevation on the outside of the cloud. Now, though there is a strong current of air rushing upwards past the barometer in the cloud, yet that barometer will stand higher than the one on the outside which is in no such under current.

The reason it will stand higher is, that there is more air over the one in the top of the cloud than over the other, on account of the expansion of the air in the cloud, and its swelling up to the very top of the atmosphere and rising higher there than in surrounding regions. Indeed, the very fact that the air spreads outwards on all sides in these high elevations from the centre of the storm, which Professor Loomis admits, and indeed proves, is itself an absolute proof that the barometer stands higher at the place *from* which the air spreads out than it does at the places *towards* which the air moves on the same horizontal level.

In the torrid zone, at the surface of the earth, the barometer stands lower than it does at latitude 30° ; yet no one who thinks will doubt that, at ten or fifteen miles above the earth's surface, the barometer would stand higher in the warm latitude than in the cold, because it is further to the top of the atmosphere where the air is more expanded by heat.

The following chart and table of barometric fluctuations are so highly important that I copy them entire, with the table of latitudes and longitudes, as a beautiful specimen of inductive philosophy. Professor Loomis, in the investigation of this magnificent storm, has added another link to the long chain of evidence that the wind blows inwards towards the centre of

storms, and also that storms of great magnitude in the United States have frequently the longest diameter nearly north and south, and move nearly side foremost towards the east.



The simplicity and uniformity of Nature, in all her great laws, lead us to believe that there is uniformity and regularity in the phenomena of storms also. Let the reader examine, in the American Phil. Transactions, Professor Loomis' original article, of which this is a very imperfect abstract, and he will see with what wonderful regularity the storm travelled from the Rocky Mountains to the Atlantic, and how the barometer everywhere rose in front of the storm and sunk on its near approach; and let him compare these facts with those detailed in other storms, both on the east and west of the Atlantic, and he will perceive that a most wonderful uniformity seems to pervade the whole.

	Latitude.	Longitude.	Bar. range.		Latitude.	Longitude.	Bar. range.
	° ' "	° ' "	Inches.		° ' "	° ' "	Inches.
Indian key	24 48 N.		.26	Twinsburgh	41 18 N.	81 26	.68
Pensacola	30 28	87 12	.46	New Haven	41 18	72 58	.98
Natchez	31 34	91 24	.79	New Bedford	41 38	70 56	1.00
Savannah	32 5	81 7	.65	Boston	42 21	71 4	.92
Bermuda	32 34	63 28	.41	Albany	42 39	73 45	1.173
Lexington	38 6	84 18	.96	Syracuse	43 1	76 15	.95
Washington	38 53	77 2	.98	Rochester	43 8	77 51	1.03
Baltimore	39 17	76 36	1.02	Hanover	43 41	72 22	1.14
Marietta	39 25	81 36	.98	Gardiner	44 10	69 50	1.00
Springfield	39 53	83 48	1.00	Halifax	44 39	63 36	.52
Philadelphia	39 57	75 11	.97	Montreal	45 31	73 35	1.266
New York	40 43	74 1	.97	Quebec	46 49	71 16	1.57
Flushing	40 45	73 52	1.042	St. John's	47 34	52 38	.85
Sunbury	40 53	76 50	1.00				

I have copied from Professor Loomis a chart of the fluctuations of the barometer in this storm, and the reader will perceive that the minimum occurred everywhere on the same meridian, in the north sooner than in the south, showing that the fluctuation travelled towards the east of south.

Professor Loomis says, in regard to this table: "It will be observed that the range of the barometer increases generally with the latitude." This is one circumstance which renders it highly probable that the storm extended to a great distance further north than the most northern observations. Another circumstance which favors this conclusion, and, indeed, renders it almost certain, is, that the wind everywhere changed round by the south to west and north west as the storm passed on.

Professor Loomis thinks "this storm moved towards the east." The barometric minimum, however, travelled from the west-northwest to the east-southeast, and it is therefore highly probable that the storm itself travelled in the same direction. Its velocity of motion, in the middle States, was about 25 or 30 miles an hour; for it moved from Springfield, Ohio, to Washington city, in twelve hours, and to Philadelphia in fourteen hours. Its motion seems to have been slower when it reached the British dominions, for it was twenty hours in passing from Quebec to Halifax, a distance of only about 400 miles. The mean velocity from west-northwest to east-southeast was not greater than 25 miles; and as the velocity of the northwest wind was certainly not less than forty miles, from the manner in which it is generally characterized—"violent gale," &c.—it follows that much of this northwest current rose on meeting the southeast current in the middle of the storm; for if none of it had ascended, the storm would have moved towards the southeast at least forty miles an hour. Professor Loomis' view, therefore, that the northwest wind flowed under the southeast, is not entirely correct; for about one-fourth as much of the northwest current ascended as of the southeast, and, on ascending, it would spread outwards above from the expansion produced by the latent heat evolved during the formation of cloud; but it would be driven chiefly towards the eastward or northeastward by the upper current of the atmosphere, which moves over the United States generally in that direction.

The barometer stood uncommonly high just before and just after this storm. On the 19th, at 2 P. M., the barometer at Philadelphia is marked, in my journal, maximum 30.73, and 22d, at 7 A. M., it had risen again to 30.61; the minimum is not marked, but on the 21st, at 7 A. M., it stood at 29.65. These maxima were produced by the outspreading of the air in the upper regions from the centre of the storm. The formation of cloud enough to make one inch of rain, would give out latent caloric sufficient to expand the air in the region where the cloud was formed, about one-forty-eighth of its whole bulk, and cause the atmospheric column to be at least a mile higher in the centre of the storm than at some distance from its borders, provided the expansion took place only upwards; but this it could not do; part of it would plainly spread outwards, and thus cause the barometer to rise on the outside of the cloud at the same moment that it fell under the middle of it. A most conclusive proof that this was the case, will be found in this: the barometer rose on the morning of the 19th 0.08 of an inch at Philadelphia, from 30.65 to 30.73; and yet the wind at that time, in most of the eastern States, was westwardly, and at most of the western ports it was easterly; at Philadelphia it was nearly calm. Now, these currents below, blowing both ways from Philadelphia, certainly

tended to make the barometer fall there. The conclusion is, that the supply of air was from above.

As to the possibility of a storm passing the Rocky Mountains, perhaps Professor Loomis is correct in deciding that it could not. And yet a storm on the western side might probably be the means of generating one on the east side in the following manner: The latent caloric evolved by the condensing vapor of the storm on the west side would cause a flood of air to swell up and roll over the mountain to the east. The first effect of this would be to raise the barometer on the east side. This would produce a western wind east of the mountain. The air, however, which crossed the mountain, containing in it the latent caloric which it had just received, being at least 30° hotter than air ordinarily is at that height, would not descend to the valley, and be a "cold, dry" wind, as Professor Loomis thinks; it would, indeed, be dry, if it descended, but, being warmer and lighter than the air through which it would have to pass, it would not descend, but flow off in all directions towards the east, the north, and the south. At the same time much of the air below would flow out in the same directions, and the effect of this would be to permit the whole upper stratum of air, containing the latent caloric, to descend to a lower level than it would otherwise have occupied. During this process, the annulus of the storm would be extending further and further to the east of the mountain, causing a rise of the barometer under its pressure, and finally, on the ceasing of the storm on the west side of the mountains, the air at the surface of the earth within the annulus would be forced back towards the mountains; there it would ascend, and if it contained the suitable quantity of vapor, the process of cloud-forming would commence, and thus a new storm would be generated on the east side of the mountains.

If I have not expressed the principle very clearly how a storm on the west side of the Rocky Mountains would be the means of generating one on the east side, let any one consider for himself what would be the result of a column of air, being expanded by heat, on the west side of the mountains, till it stood three or four miles higher than a column on the east side, and he will perceive, by his own intellect, that there is some reason for the conclusion above.

He will readily see, also, that a wind, blowing across the Rocky Mountains from west to east, producing rain on the west side, cannot become a "cold wind on the east."

He might, indeed, conclude that it would produce no effect on the temperature at all, as it swims on the top of the atmosphere; but in this he would be wrong, for it would increase the temperature at the surface of the earth by its radiation. The efflux of air above, from the borders of a great storm cloud, often produces an increase of temperature below by radiation, before the storm comes upon us, or any southern wind. It is a prevailing idea that air does not radiate caloric. But this cannot be true; for it is the upper regions of the air, or at least a considerable distance above the surface of the earth, where the latent caloric of vapor is given out, in the formation of clouds, a quantity sufficient, in many countries where sixty or eighty inches of rain fall, to heat it in one year six or eight hundred degrees. All this it must gradually part with, by radiation, after each successive rain.

It may, perhaps, be objected that, as the upper regions of the air, even in their warmest state, are much colder than the lower, they can never be said to warm the lower regions by their radiation; but this objection will vanish, when we consider that the surface of the earth would become much colder in a given time by radiation, if it received no heat from the upper

regions of the atmosphere, and from the celestial vault in the evening, when the sun's rays are withdrawn. M. Pouillet has made a most ingenious attempt, by means of an actinometer of his own invention, to ascertain, approximately, the quantity of heat which is radiated from the upper regions of the air to the surface of the earth, and also the quantity which is radiated from the fixed stars; and if his experiments do not settle the question, they at least prove that the quantity of caloric reaching the earth from those two sources is not inconsiderable; and also that the upper regions of the air cool many degrees during the night when they are receiving no heat from the sun. A wide field of investigation is here laid open to the future meteorologist; and I would recommend to every one who shall undertake to pursue this subject further, to observe the effect of the formation of dew on the actinometer, and also to take into account the latent caloric received in the upper strata of the atmosphere during storms of rain and snow.

Much may be learned on this subject, without an actinometer of M. Pouillet's construction, by a continued series of experiments of the following nature:

Place a thermometer on some bad conductor of caloric—the inside of a common washing tub, for example, whose bottom is covered three or four inches thick with straw, or charcoal, or wool, and expose the whole so arranged, on the ground, under the open sky, free from the radiation of surrounding houses, and note from hour to hour every evening the difference between this thermometer and one swung briskly in the air near the tub. The more the thermometer at rest sinks below the one in motion, the colder will it indicate the upper regions of the atmosphere to be, except when dew is formed; when this takes place, the further depression of the thermometer at rest is greatly diminished by the evolution of latent caloric; and this will frequently happen when there is no dew formed on the ground round about.

May it not be possible that the approach of a distant storm might be discovered by this means?

74. The following article appeared in the Philadelphia Saturday Courier, of March 18, 1837.

Its value is much increased by Professor Loomis' investigation of the same storm.

MR. EDITOR: On reading in the London papers recently arrived the account of the remarkable snow-storm that passed over England on the 24th, 25th, and 26th of December, my attention was recalled to some circumstances connected with the no less remarkable storm that traversed Pennsylvania on the evening of the 20th and morning of the 21st of the same month.

The approach of that storm was announced by the chairman of the Joint Committee on Meteorology of the Philosophical Society, and the Franklin Institute of Pennsylvania, at their session on Monday evening, the 19th December. The substance of Mr. Espy's communication was, that on a reference to the observations of Gouverneur Emerson, M. D., and his own, it appeared that the barometer had risen during the last twenty-four hours 1.05 of an inch; that it attained its maximum height at 7 P. M., and was then, at 8 P. M., beginning to descend; that such a rise of the barometer had not been observed in the same period of time for several years; that this and other phenomena noticed at the time induced him to think that we were then in the eastern part of the annulus or border of a violent storm; that though perfectly clear and calm at that time, it was reasonable to expect that the wind would set in from the east next morning; that in such a case it would be certain that in twenty-four hours—that is to say, by the evening of the 20th—the storm would reach this place, and would rage with a violence pro-

portioned to the extraordinary rise of the barometer which preceded it; that the deposit of snow or rain would, for the same reason, be very great.

For proof that the prediction was fully realized, I refer you to the account published in the journals of that date. The wind changed to the east next morning, the 20th, and the rain at this place, and snow further north, commenced falling on the evening of the same day, and closed on the morning of the 21st. Serious damage was done to the shipping in the Delaware, and at all our northeastern ports, and off the coast. At Buffalo, the wind drove a portion of the water of Lake Erie into the city, and it was stated in the gazettes of that date that a building was set on fire at Buffalo by the slacking of lime from water driven eastward by the force of the gale.

Dr. Franklin first ascertained that all storms travel towards the northeast.*

Mr. Espy's researches led him to believe that this constancy of direction in this locality is confined to our winter storms and summer tornadoes. He has also found, from observations furnished by Professor Hamilton, that in the winter season the rise of the barometer, as well as the presence of the centre of the storm, takes place at Nashville, Tennessee, about twenty-four hours earlier than at Philadelphia.

And here I would remark, that Dr. Emerson is the first observer, so far as my knowledge extends, who noticed that a great rise of the barometer is a prelude to a northeasterly storm—a conclusion to which Mr. Espy has arrived, *a priori*, from his theory of storms. This conclusion is in direct opposition to popular opinion, and, indeed, to that of most philosophers, who have marked set fair on the barometer at one inch above the mean.

If I mistake not, Mr. Espy has somewhere stated in his lectures that remarkable barometric fluctuations were often noticed to occur in the winter season about four or five days later at London than here, indicating that the centre of the storms to which these fluctuations owe their origin traverse three thousand miles of a rhomb line on the surface of the earth in that period of time, being at an average rate of about twenty-two miles per hour.

If the storm in Pennsylvania, of the 20th and 21st, followed such a course at that rate, the annulus or atmospheric wave which caused the remarkable rise of the barometer here must have reached London about the 23d or 24th, and must have been the harbinger of the approaching storm at that place, the violence of which should be proportioned to the excess above the mean of the density of the atmospheric wave which preceded it. The storm lasted one day at this place and three days at London, showing that its linear dimensions were three times as great there as here. The middle of the storm, or time of greatest depression of the barometer, was during the forenoon of the 20th, and should have been on the 25th or 26th at London, if these two storms were the same. Take from this date a day and a half for the semi-duration, and twenty-four hours for the period which the point of greatest atmospheric density preceded the beginning of the snow, and we have the 23d for the date of the greatest rise of the barometer at London, according to Mr. Espy's theory.

Whether such a rise and depression of the barometer was observed in London, or not, remains to be learned. It is by no means improbable, however, that if observations in the whole intermediate space on our northern coast and on the Atlantic ocean could be obtained, the remarkable storm of the 25th and 26th of December would be found to be the same which did so much harm to the shipping in our ports and off our coast on the night of the 20th and the morning of the 21st.

* Since discovered that storms travel towards the east, or south of east.

Should such be found to be the case, it will then be an important subject of inquiry, whether the unusual retardation of our homeward bound vessels from Europe in December, and the lateness of their arrival in January, after a passage of forty and sometimes fifty days, and, in short, whether the appalling losses sustained by our insurance offices at that period, were not, in some degree, owing to their track being crossed by this violent storm, whose width in the direction of their course must have been near fifteen hundred miles? Should such a circumstance be shown to be probable, then would the occurrence of similar meteorological phenomena in the winter months on land be regarded as the prelude to similar disasters at sea; the foresight of the merchant and underwriter and the protecting hand of government would be directed to the means of affording relief to those vessels and crews at sea which may be presumed to be in distress from the perils which it is known they must have encountered.

My motive in making this public testimonial of the correctness of Mr. Espy's announcement on the 19th of December, as a practical illustration of his theory, has been to suggest the propriety of concert among observers in this important department of science, for the purpose of learning more fully the course of storms and tornadoes in traversing the earth's surface.

Many observations important to pilots and navigators might be elicited on a subject in which every step of advancement made, and every peril removed or obviated, is fraught with the happiest consequences to society.

While engaged on this subject, it is proper to mention that a valuable contribution to the science of meteorology is contained in a memoir on "The Gales and Hurricanes of the Western Atlantic," published last summer, by Mr. W. C. Redfield, in the Transactions of the Naval Lyceum.

Yours, truly,

S. C. WALKER.

P. S. Since writing the above, I have been favored by Dr. Emerson with the perusal of a letter addressed to him by his correspondent, Mr. Gardiner, of Gardiner, Maine, which states that the barometer attained its maximum height in the afternoon of the 20th, and its minimum at 5 P. M. of the 21st; that there was a violent gale at 7 A. M. of the 21st, and that the rain commenced at 10 P. M. same day. Thus the principal phases of this storm at Gardiner, Maine, occurred almost a day later than here, and they furnish a link in the chain of evidence required to warrant a just and definite conclusion concerning the identity of these two storms.

S. C. W.

SYNOPSIS.*

75. When the air near the surface of the earth becomes more heated or more highly charged with aqueous vapor, which is only five-eighths of the specific gravity of atmospheric air, its equilibrium is unstable, and up-moving columns or streams will be formed. As these columns rise, their upper parts will come under less pressure, and the air will therefore expand. As it expands, it will grow colder about one degree and a quarter for every hundred yards of its ascent, as is demonstrated by experiments on the nephelescope. The ascending columns will carry up with them the aqueous vapor which they contain, and, if they rise high enough, the cold produced by expansion from diminished pressure will condense some of this vapor into cloud; for it is known that cloud is formed in the receiver of an air pump when the air is suddenly withdrawn. The distance or height to which the air will have to ascend before it will become cold enough to begin to form cloud is a variable quantity, depending on the number of degrees which the dew-point is below the temperature of the air; and this height may be known

*See Phil. of storms. Introduction page 8.

at any time by observing how many degrees a thin metallic tumbler of water must be cooled down below the temperature of the air before the vapor begins to condense on the outside. The highest temperature at which it will condense, which is variable accordingly as there is more or less vapor in the air, is called the "dew-point," and the difference between the dew-point and the temperature of the air in degrees is called the complement of the dew-point.*

It is manifest that if the air at the surface of the earth should at any time be cooled down a little below the dew-point, it would form a fog by condensing a small portion of its transparent vapor into little fine particles of water; and if it should be cooled twenty degrees below the dew-point, it would condense about one-half its vapor into water; and at forty degrees below, it would condense about three-fourths of its vapor into water, &c. This, however, will not be exactly the case from the cold produced by expansion in the up-moving columns, for the vapor itself grows thinner, and the dew-point falls about one-quarter of a degree for every hundred yards of its ascent.

It follows, then, as the temperature of the air sinks about one degree and a quarter for every hundred yards of ascent, and the dew-point sinks about a quarter of a degree, that as soon as the column rises as many hundred yards as the complement of the dew-point contains degrees of Fahrenheit, cloud will begin to form; or, in other words, the bases of all clouds forming by the cold of diminished pressure from up-moving columns of air will be about as many hundred yards high as the dew-point in degrees is below the temperature of the air at the time. If the temperature of the ascending column should be ten degrees above that of the air through which it passes, and should rise to the height of 4,800 feet before it begins to form cloud, the whole column would then be 100 feet of air lighter than surrounding columns; and if the column should be very narrow, its velocity of upward motion would follow the laws of spouting fluids, which would be eight times the square root of 100 feet a second—that is, 80 feet a second—and the barometer in the centre of the column at its base would fall about the ninth of an inch. As soon as cloud begins to form, the caloric of elasticity of the vapor or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapor. This will prevent the air, in its further progress upwards, from cooling so fast as it did up to that point; and, from experiments on the nephelescope, it is found to cool only about one-half as much above the base of the cloud as below—that is, about five-eighths of a degree for one hundred yards of ascent—when the dew-point is about seventy degrees. If the dew-point is higher, it cools a little less; and if the dew-point is lower, it cools a little more than five-eighths of a degree in ascending one hundred yards.

Now, it has been ascertained by aeronauts and travellers on mountains that the atmosphere itself, free from clouds, is about one degree colder for every hundred yards in height above the surface of the sea; therefore, as the air in the cloud above its base is only five-eighths of a degree colder for every hundred yards in height, it follows that, when the cloud is of great perpendicular height above its base, its top must be much warmer than the atmosphere at that height, and consequently much lighter. Indeed, the specific gravity of a cloud of any height, compared with that of the surrounding air at the same elevation, may be calculated when the dew-point is given; for its temperature is known by experiments with the nephelescope, and the quantity

* The height of the bases of forming cumuli may be ascertained by the following empirical formula: $10300 \left(\frac{t - t^1}{t^1} \right)$
 = height of base in yards; t being the temperature of the air in degrees of Fahrenheit, and t^1 the temperature of wet bulb swung briskly in the air.

of vapor condensed by the cold of diminished pressure at every point in its upward motion, and of course the quantity of caloric of elasticity given out by this condensation is known, and also the effect this caloric has in expanding the air receiving it beyond the volume it would have if no caloric of elasticity was evolved in the condensation of the vapor. For example, according to the experiments of Professor W. R. Johnson, of Philadelphia, a pound of steam, at the temperature of 212° , contains $1,030^{\circ}$ of caloric of elasticity; and as the sum of the latent and sensible caloric of steam is the same at all temperatures, it follows, that a pound of steam being condensed in 1,210 pounds of water at 32° , would heat this water up one degree; and, as the specific caloric of air is only 0.267, if a pound of vapor should be condensed in 1,210 pounds of air, it would heat that air nearly 4° ; or, which is the same thing, it would heat 100 pounds of air about 45° . And in all these cases it would expand the air about 8,000 times the bulk of water generated—that is, 8,000 cubic feet for every cubic foot of water formed out of the condensed vapor. And as it requires about 1,300 cubic feet of vapor, at the ordinary temperatures of the atmosphere, to make one cubic foot of water, if this quantity be subtracted from 8,000, it will leave 6,700 cubic feet of actual expansion of the air in the cloud for every cubic foot of water generated there by condensed vapor. When hail or snow is formed, the caloric of fluidity given out will produce about an eighth greater expansion. This great expansion of the air in the forming cloud will cause the air to spread outwards in all directions above, causing the barometer to rise on the outside of the cloud above the mean, and to fall below the mean under the middle of the cloud as much as it is known to do in the midst of great storms. For example, if the dew-point should be very high, say 78° , then the quantity of vapor in the air would be about one-fiftieth of its whole weight; and if the up-moving column should rise high enough to condense one-half its vapor into cloud, it would heat the air containing it 45° , and the air so heated would be $\frac{45}{448}$ larger than it would be if it was at zero, and not so heated. And if we assume a case within the bounds of nature, and suppose the cloud and the column under the cloud to occupy three-fourths of the whole weight of the atmosphere; or, in other words, if we suppose the top of the cloud to reach a height where the barometer would stand at $7\frac{1}{2}$ inches, and the mean temperature of the whole column 40° warmer than the surrounding air, (which we may suppose, for the sake of illustration, to have a mean temperature of zero,) then would the barometer fall under the cloud at the surface of the earth $\frac{40}{448}$ of 22.5 inches, or a little more than two inches.

Though the air will be driven up much higher than the point here assumed, and of course increase the depression of the barometer, from its specific levity, the cloud will cease to form at greater heights, because the dew-point, at these great elevations, falls by a further ascent as rapidly as the temperature; and at greater elevations it will fall more rapidly. If, for instance, the air should rise from where the barometer stands at six inches to where it stands at three inches, the dew-point would fall about 20° , but the temperature would fall less than 20° , and therefore no vapor would be condensed by such ascent. When a cloud begins to form from an ascending column of air, it will be seen to swell out at the top, assuming, successively, the appearances of 1, 2, 3, generally called cumuli; or, if the up-moving current should be driven out of its perpendicular motion by an upper current of air, the clouds which might then form would be ragged and irregular, called broken cumuli, as 4. These will always be higher than the base of cumuli, but much lower than cirrus. While the cloud continues to form and swell

up above, its base will remain on the same level, for the air below the base has to rise to the same height before it becomes cold enough, by diminished pressure, to begin to condense its vapor into water; this will cause the base to be flat, even after the cloud has acquired great perpendicular height, and assumed the form of a sugar loaf. Other clouds, also, for many miles around, formed by other ascending columns, will assume similar appearances, and will, moreover, have their bases all on the same, or nearly the same, horizontal level; and the height of these bases from the surface of the earth will be greatest about two o'clock, when the dew-point and temperature of the air are the greatest distance apart. The outspreading of the air in the upper parts of an ascending column will form an annulus all round the cloud, under which the barometer will stand above the mean; of course the air will sink downwards from its greater weight in the annulus, and increase the velocity of the wind at the surface of the earth towards the centre of the ascending column, while all round on the outside of the annulus there will be a gentle wind outwards. Any general currents of air, which may exist at the time, will of course modify these motions from the oblique forces they would occasion. The up-moving current of air must, of course, be entirely supplied by the air within the annulus, and that which descends in the annulus itself.

When up-moving currents are formed by superior heat, clouds will more frequently begin to form in the morning, increase in number as the heat increases, and cease altogether in the evening, when the surface of the earth becomes cool by radiation.

The commencement of up-moving columns in the morning will be attended with an increase of wind, and its force will increase with the increasing columns—both keeping pace with the increasing temperature. This increase of wind is produced partly by the rush of air on all sides at the surface of the earth towards the centre of the ascending columns, producing fitful breezes; and partly by the depression of air all round the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface.* The rapid disturbance of equilibrium,

* On the comparative force of the wind during the twenty-four hours, by Mr. Osler:

Mr. Follet Osler brought before the British Association a paper, in which he gave the results of his investigations respecting the direction and force of the wind, deduced from the mean of 26,000 hourly observations, taken by the anemometer at the Philosophical Institution, at Birmingham, during the years 1837, 1838, and 1839. We extract one of Mr. Osler's tables:

Table showing the relative force of the wind for each hour of the day, distinguishing the seasons, from a mean of the years 1837, 1838, and 1839.

	A. M.												P. M.											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Winter.....	55	54	49	47	47	48	48	51	50	67	73	82	89	89	85	70	75	65	63	63	63	59	61	57
Spring.....	26	28	28	27	29	29	32	41	56	70	80	82	90	89	89	80	81	72	52	45	46	38	33	29
Summer.....	19	19	19	19	22	20	18	21	25	40	47	55	58	54	53	44	34	28	27	24	22	19	21	20
Autumn.....	19	19	19	19	22	20	18	21	26	40	47	55	58	54	53	44	34	28	27	24	22	20	21	20
Total.....	119	120	115	112	120	117	116	134	157	217	247	274	295	286	280	247	224	193	169	156	153	136	136	126

As direction is not regarded in this table, a total of more than one thousand observations is given for each hour of the day. In tabulating these, the curve obtained is found to be almost identical with that of the thermometer, not only for the whole year, but for each season. The increase in the temperature, however, precedes the rise of the wind by a short interval, until it has attained its maximum force; but as evening approaches, the wind declines more rapidly than the temperature.

which is produced by one ascending column, will tend to form *others* in its neighborhood; for the air being pressed outwards from the annulus, or at least retarded on the windward side, will form other ascending columns, and these will form other annuli, and so the process will be continued. These ascending columns will have a tendency to approach, and finally unite; for the air between them, as between, must descend, and in descending the temperature of the whole column will increase; for it is known that the air, at great elevations, contains more caloric to the pound than the air near the surface of the earth, because it is the upper regions that receive the caloric of elasticity given out in the condensation of vapor into clouds. Therefore, when the air has descended sometime in the middle, between two ascending columns, the barometer will fall a little, or at least not stand so high above the mean as it does on the outside of the two clouds, and so the columns will be pressed towards each other. If one of two neighboring columns should be greatly higher than the other, its annulus may overlap the smaller one, and, of course, the current under the smaller cloud will be inverted, and the cloud which may have been formed over the column thus forced to descend will soon disappear; for, as it is forced downwards by the overlapping annulus of the more lofty column, it will come under greater pressure, and its temperature will be thus increased and it is manifest that, as soon as its top descends as low as its base, it will have entirely disappeared, and in the mean time, the larger cloud will have greatly increased.

As the air above the cloud, formed by an ascending column, is forced upwards, if it contains much aqueous vapor, a thin film of cloud, will be formed in it by the cold of diminished pressure, entirely distinct from the great dense cumulus below; but as the cumulus rises faster than the air above it, (for some of the air will roll off,) the thin film and the top of the cumulus will come in contact, and sometimes a second film or cap may be formed in the same way, and perhaps a third and fourth. When these caps form, there will probably be rain, as their formation indicates a high degree of saturation in the upper air.

When the complement of the dew-point is very great, (twenty degrees and more,) clouds can scarcely form; for up-moving columns will generally either come to an equilibrium with the surrounding air, or be dispersed before they rise twenty hundred yards, which they must do in this case, before they form clouds. Sometimes, however, masses of air will rise high enough to form clouds, but they are generally detached from any up-moving column underneath, and, of course, cannot then form cumuli with flat bases; such clouds will be seen to dissolve as soon as they form, and, even while forming, they will generally appear ragged, thin, and irregular. Moreover, if the ground should be colder during the day than the air in contact with it, as it sometimes happens after a very cold spell of weather, then, as the air touching the cold earth will be colder than the stratum above it, ascending columns cannot exist, and, of course, no cumuli can be formed on that day, even though the air may be saturated with vapor to such a degree as to condense a portion of it on cold bodies at the surface of the earth. Also, if, during the whole winter, any part of Siberia, or the northern part of North America, should be so much colder than surrounding regions that no up-moving columns could be produced, then neither clouds nor snow could be formed. Neither can clouds form of any great size when there are cross currents of air sufficiently strong to break in two an ascending current, for the ascensional power of the up-moving current will thus be weakened and destroyed. Immediately after a great rain, too, when the upper air has yet in it a large quantity of caloric, which it

received from the condensation of the vapor, the up-moving columns which may then occur, on reaching this upper stratum, will not continue their motion in it far from the want of buoyancy; therefore, they will not produce rain, nor clouds of any kind, but broken cumuli. Besides, as the air at some distance above the surface of the earth and below the base of the cloud is sometimes very dry, and as much of this air goes in below the base of the cloud, and up with the ascending column, large portions of the air in the cloud may thus not be saturated with vapor, and, of course, rain in this case will not be produced. Professor Stevelly, of Belfast, told the author that he knew that clouds are sometimes not saturated. These are some of the means contrived by nature to prevent up-moving columns from increasing until rain would follow. Without some such contrivances, it is probable that every up-moving column which should begin to form cloud when the dew-point is favorable would produce rain; for as soon as cloud forms, the up-moving power is rapidly increased by the evolution of the caloric of elasticity.

On the leeward side of very lofty mountains there cannot be rain; for as the air on the windward side rises up the sides of the mountain, it will condense all the vapor which can be condensed by the cold of diminished pressure before it reaches the top; and even if the cloud passes over the top to the other side, it would soon disappear, because in passing down the slope it will come under greater pressure, and thus be dissolved by the heat produced.

These are some of the causes which prevent rains at particular times and in particular localities. If, however, the air is very hot below, with a high dew-point, and no cross currents of air above to a great height, then, when an up-moving current is once formed, it will go on and increase in violence as it acquires perpendicular elevation, especially after the cloud begins to form. At first, the base of the cloud will be flat; but after the cloud becomes of great perpendicular diameter, and the barometer begins to fall considerably, as it will do from the specific levity of the air in the cloud, then the air will not have to rise so far as it did at the moment when the cloud began to form, before it reaches high enough to form cloud from the cold of diminished pressure. The cloud will now be convex below, and its upper parts will be seen spreading outwards in all directions, especially on that side towards which the upper current is moving, assuming something of the shape of a mushroom. In the meantime the action of the in-moving current below and up-moving current in the middle will become very violent; and if the barometer falls two inches under the centre of the cloud, the air, on coming in under the cloud, will cool, by diminished pressure, about ten degrees, and the base of the cloud will reach the earth, if the dew-point was only eight degrees below the temperature of the air at the time the cloud began to form. The shape of the lower part of the cloud will now be that of an inverted cone, with its apex near the ground, and when a little more prolonged and fully developed, it will be what is called a tornado, if it is on land, and a water-spout, if at sea.

On visiting the path of a tornado, the trees on the extreme borders will all be found prostrated with their tops inwards, either inwards and backwards, or inwards and forwards, or exactly transverse to the path. The trees in the centre of the path will be thrown either backwards or forwards, or parallel to the path; and invariably, if one tree lies across another, the one which is thrown backwards is underneath. Those materials on the sides which are moved from their places and rolled along the ground, leaving the trace of their motion, will move in a curve convex

behind; those which were on the right hand of the path will make a curve from left hand to right; and those on the left hand of the path will make a curve from right hand to left; and many of these materials will be found on the opposite side of the path from that on which they stood on the approach of the tornado, being carried beyond the centre by their momentum, and moved a little forward by the rear of the tornado. Also, those bodies which are carried up will appear to whirl, unless they arise from the very centre; those that are taken up on the right of the centre will whirl in a spiral from left to right; and those on the left of the centre will whirl in a spiral upward from right to left. On examining the trees which stand near the borders of the path, it will be found that many of the limbs are twisted round the trees, and broken in such a manner as to remain twisted—those on the right side of the path from left to right, and those on the left side of the path from right to left. However, it will be found that only those limbs which grew on the side of the tree most distant from the path of the tornado are broken, for those alone were subject to a transverse strain. The houses which stood near the middle of the path will be very liable to have the roofs blown up; and many of the walls will be prostrated, all outwards, by the explosive influence of the air within; and those houses covered with zinc or tin, from being air-tight, will suffer most. The floors from the cellars will also frequently be thrown up, doors and windows burst outwards, and bureaus and corks of empty bottles exploded. All round the tornado, at a short distance, probably not more than three or four hundred yards, there will be a dead calm on account of the annulus formed by the rapid efflux of air above from the centre of the up-moving and expanding column. In this annulus the air will be depressed, because the barometer stands above the mean there, and all round on the outside of it, at the surface of the earth, there will be a gentle wind outwards, and, of course, all the air which feeds the tornado is supplied from within the annulus. Nor is this difficult to understand, when the depression of the air in the annulus is considered, for any amount may be thus supplied by a great depression. Light bodies, such as shingles, branches of trees, sand, pollen of plants in bloom, grain, fishes, frogs, and tadpoles, and drops of rain or water formed in the cloud, will be carried up to a great height before they are permitted to fall to the earth, provided there is no whirl to throw them out by a centrifugal force; for though they may frequently be thrown outwards above, and then descend to a considerable distance at the side, they will meet with an in-blowing current below, which will force them back to the centre of the up-moving current, and so they will be carried aloft again.

The drops of rain, however, will frequently be carried high enough to freeze them, especially if they are thrown out above so far as to fall into clear air, for this air will in some cases be thirty or forty degrees colder than the air in the cloud. In this case, if the up-moving column is perpendicular, the hail will be thrown out on both sides, sloping inwards as it falls; and on examination it will be found that two veins of hail fell simultaneously at no great distance apart. This hail will frequently be found to contain many of the materials which were carried up from the surface of the earth; and in cases of violent action, sheets of water will be frozen into cakes of ice; which will break into all sorts of shapes and angles on reaching the surface of the earth. It is, indeed, probable that, in all violent thunder storms in which hail falls, the up-moving current is so violent as to carry drops of rain to a great height, when they freeze and become hail. It is difficult, if not impossible, to conceive any other way in which hail can

be formed in the summer, or in the torrid zone. In those countries in which an upper current of air prevails in a particular direction, the tornadoes and waterspouts will generally move in the same direction, because the up-moving column of air in this meteor rises far into this upper current, and, of course, its upper part will be pressed in this direction ; and as the great tornado cloud moves on in the direction of the upper current, the air at the surface of the earth will be pressed up into it by the superior weight of the surrounding air. It is for this reason that the tornado in Pennsylvania generally moves towards the eastward. The *lower* current does not give direction to the hurricanes of the West Indies, for in the latitude of 15° north the prevailing direction of the trade winds is northeasterly, and there the hurricanes move towards the northwest. It is probable, however, they sometimes bend out of their course to pass over an island lying near the track, which they would otherwise pursue.

If a tornado should stop in its motion for a few seconds, as it might do, on meeting with a mountain, it would be likely to pour down an immense flood of water or ice in a very small space, for the drops which would be carried up by the ascending current would soon accumulate to such a degree as to force their way back, and this they could not do without collecting into one united stream of immense length and weight, and, of course, on reaching the side of the mountain, this stream, whether it consisted of water or hail, would cut down into the side of the mountain a deep hole, and make a gully all the way to the bottom of the mountain, from the place where it first struck.

As the air spreads out more rapidly above than it runs in below, there will be a tendency in storms to increase in diameter, and this tendency will be greater on the north side than on any other, for the efflux above finds less resistance on that side, for a reason assigned in the next paragraph ; therefore, it is probable that storms become elongated north and south, and then, if they move towards the east, they must travel side foremost. At the equator, or at least those parts of it where the trade winds are constant from east to west, it is probable tornadoes travel from east to west. For, as the air in the torrid zone is about 80° in temperature at a mean, and the air in the frigid zone is about zero, the air in the torrid zone is constantly expanded by heat about $\frac{80}{448}$ of its whole bulk in the frigid zone. This will cause the air at the equator to stand more than seven miles higher from the surface of the earth to the top of the atmosphere than at the north pole. The air, therefore, will roll off from the torrid zone both ways towards the poles, causing the barometer to fall in low latitudes, and rise above the mean in high latitudes. This will cause the air to run in below towards the equator, and, of course, rise there. Now, from the principle of the conservation of areas, it will recede more and more to the west as it rises, and, of course, the upper current of the air at the equator probably moves towards the west. However, as the air rolls off above, towards the north, it will be constantly passing over portions of the earth's surface, which have a less diurnal velocity than the part from which it set out ; and as from the nature of inertia it still inclines to retain the diurnal velocity towards the east, which it originally possessed, when it reaches the latitude of about 20 or 25 degrees, it will then probably be moving nearly towards the north, and beyond that latitude its motion will be northeasterly. The effect of the air rolling off above from the equator towards the poles, when considered alone, would cause the barometer at the very poles to stand above the mean ; but the centrifugal force of the air in the frigid zone, arising from the diurnal revolution of the earth on her axis, produces a countervailing force of considerable power, and flattens

the atmosphere at the poles more than the earth is flattened, because it is of greater diameter, and perhaps this may cause the barometer to stand below the mean very near the poles. Let this matter be further examined.* As the air in the torrid zone certainly does rise and run out towards the poles above, it *must rise* there in columns, and not all over the zone at once; otherwise, this whole zone would be covered with eternal cloud, formed by the condensation of the vapor from the cold of diminished pressure as the air ascended.

If violent storm clouds, which necessarily rise to a great height in the upper current, are driven forward in the direction of the upper current, it is probable that the barometer will rise higher in that part of the annulus which is in front of the storm than in the rear; and if so, a sudden rise of the barometer, in particular localities, may become, when properly understood, one of the first symptoms of an approaching storm. In consequence of the high barometer in front of the storm in a semi-annulus, the air will be forced downwards there, and cause, in some cases, a more violent action of the air or wind backwards, meeting the approaching storm, than will be experienced in the rear of the storm. As the barometer will probably be highest in the centre of the semi-annulus, northeast of the storm, in middle latitudes, the tendency of the wind to blow outwards on all sides from the region where the barometer stands highest may cause the wind in the beginning of the storm to blow so as to appear to whirl from left to right on the south side of the storm, and from right to left on the north side.

As the air comes downwards in the semi-annulus in front of the storm, it will come under greater pressure, and, therefore, any clouds which it may contain will probably be dissolved by the heat of greater pressure; consequently, on the passage of the annulus, it will probably be fair weather. Also, as the air above always contains more caloric to the pound than the air below, more especially that which has just spread out above from a storm cloud, containing the caloric recently evolved from the condensing vapor, there will be an increase of temperature on the passage of the annulus, partly from the increased pressure, partly from the increased radiation of the hotter air above, but chiefly by the descent of the air itself. In very hot climates this increase of temperature in front of the storm will be very sensibly felt. The increased pressure in the annulus round a volcano when it suddenly bursts out will sometimes, under favorable circumstances, be very great, and, of course, the air will be depressed from a great height, so that some portion of the very air which has gone up in the central parts of the ascending column, and formed cloud by the cold of diminished pressure, may be forced down to the surface of the earth, bringing with it the caloric of elasticity which it received from the condensing vapor; if so, the heat experienced at the time of this descent will be very great.

These hot blasts of air will alternate with cold blasts; for the air which is forced down from great heights in the annulus will not only be very hot, but very dry, having condensed its vapor in its previous ascent. Now, when this hot, dry air flows inwards again towards the volcano and ascends, it will not form cloud because of its want of vapor, and therefore the process of cloud-forming will cease, and, consequently, hail and rain will cease, too, until more air from a greater distance, that has not been deprived of its vapor, flows in and ascends. Then cloud will again begin to form, and the violence and rapidity of the out-flowing of the air above will be increased by the evolution of the caloric of elasticity; the barometer will rise rapidly in the annulus, and fall in the central part of the ascending column; and these alterna-

* It is found since that the barometer stands high at the poles. (See 94-110.)

tions may continue while the volcano is in activity, more particularly if the violence of the volcano itself should be increased periodically.

As air cannot move upwards without coming under diminished pressure, and as it must thus expand and grow cooler, and consequently form cloud, any cause which produces an up-moving column of air, whether that cause be natural or artificial, will produce rain when the complement of the dew-point is small, the air calm below and above, and the upper part of the atmosphere of its ordinary temperature.

Volcanoes, therefore, under favorable circumstances, will produce rain; sea breezes, which blow inwards every day towards the centre of islands, especially if these islands have in them high mountains which will prevent any upper current of air from bending the up-moving current of air out of the perpendicular before it rises high enough to form cloud, such as Jamaica, will produce rain every day; great cities, where very much fuel is burnt, in countries where the complement of the dew-point is small, such as Manchester and Liverpool, will frequently produce rain; even battles and accidental fires, if they occur under favorable circumstances, may sometimes be followed by rain. Let all these favorable circumstances be watched for in time of drought, (and they can only occur then,) and let the experiment be tried; if it should be successful, the result would be highly beneficial to mankind. It might probably prevent the occurrence of those destructive tornadoes which produce such devastation in the United States; for, if rains should be produced at regular intervals of no great duration, the steam power in the air might thus be prevented from rising high enough to produce any storm of destructive character.

Besides its utility to the farmer, it would be highly useful to the mariner in the following way: As the very time and place of the commencement of the rain would be known, it would be easy to find out in what direction, from the place of beginning, it moved along the surface of the earth, and also its velocity of motion, and the shape that it assumed from time to time in its progress; and this knowledge being extended to the motion of storms on the ocean, will enable the mariner, who has the power of locomotion, to direct his vessel so, when one of these great storms comes near him, that he can use as much wind in the borders of the storm as will suit the purposes of navigation—for Heaven undoubtedly makes the wind blow for his use, and not for his destruction, provided he becomes acquainted with the laws which govern its motions. From the preceding principles, he will be able to know in what direction a great storm is raging, when it is yet several hundred miles from him, for the direction of the wind alone points it out. If, however, the storm should be of such great length, moving side foremost, that it will preclude the possibility of avoiding it, he will at least be enabled to know in what direction to steer his ship to get out of the storm as soon as possible. For example: if it shall be found that storms between the United States and Europe always move towards the east, then it will manifestly be improper to scud with the wind in the latter part of the gale, when the wind is blowing from the westward, because this would be to keep in the storm as long as possible. The sailor, also, will be able to know when he is out of danger; for, when a great storm has passed off to the east in middle and high latitudes, and to the north in low latitudes, on the north of the equator, he will know that it never returns, and therefore he will not be afraid to spread his sails to the wind before the calm of the annulus comes upon him. The mariner will

finally be able, by observing storm clouds on their approach, to ascertain the direction in which storms move, for these storm clouds frequently exhibit their front edge above the horizon in the form of an arch; and if the highest part of the arch approaches towards the zenith, then is the storm coming from the point where the arch first appeared.

When a storm has a much greater diameter from north to south than from east to west, the wind will not blow towards a central point, but towards a central line, which may be called the transverse diameter of the storm.

On the northern end of the storm, if it moves towards the east, the wind will change round, without a lull, by north towards the west; and on the southern end of the storm the wind will change round, without a lull, by south towards the west; but in the middle of the storm the wind will change, with a lull, from easterly to westerly.

When the storm is of great length, north and south, the lull in the central parts may be experienced simultaneously at considerable distances apart, north and south, which could not be the case if the storm was round; and as this occurs frequently on the coast of the United States, it is certain, from that circumstance alone, that the centre of storms is frequently a line of great length; and, moreover, as the wind in the first part of the storm is frequently south-east, and in the last part of the storm northwest, and as the barometer falls successively from north of west to south of east, it seems highly probable that these storms of oblong form move towards the south of east.

In the West Indies, from Barbadoes to Jamaica, it is known, by the invaluable labors of Redfield and Reid, that the hurricanes there move from the southeast to northwest; therefore, if the wind springs up violent from northwest in those parts, the mariner may be sure that a hurricane is coming upon him if he remains stationary; and if it springs up in any other direction, he will know in what direction to sail to avoid its violence.*

This paper gave rise to a very interesting conversation, but, from the great length of the paper itself, we can only direct attention to the leading points of the discussion. Professor Stevelly called the attention of the Section to the fact that he had, at the Edinburgh meeting in 1834, used the principle of cold, produced by rarefaction, to explain what he called the secondary formation of clouds, and thus the propagation of storms, and even assigned this rarefaction as the cause of summer hail.

He objected to the main position, however, in Mr. Espy's theory, that the *fall of temperature*, caused by the expansion of any body of air rendered light by being loaded with moisture as it rose in the atmosphere, was the same as the *constituent temperature of the strata of air* into which it rose—that is, of equal tension. He deduced, from the numbers given by Poisson, that it was much greater; that a cloud would be colder and not hotter than the surrounding air, and therefore the violent ascending vortex calculated upon by Mr. Espy would not exist.

Professor Forbes had three objections to Mr. Espy's theory: 1st. The small funnel at the centre of a tornado, through which Mr. Espy supposed the air to rise, would be insufficient to vent all the air which would rush, during a tornado, with the frightful velocity we know it to attain, through the constantly enlarging rings surrounding that central funnel, to an extent of many hundred miles. 2d. As the tornado had a progressive motion, as Mr. Espy admitted, it would be more difficult than Mr. Espy supposed to deduce, from the way in which the trees in

* This paper was read before the British Association.

its path were thrown, the actual course of the atmospheric particles at any instant, as each would move with a motion compounded of two motions, both varying in relative direction and magnitude. 3d. He thought that all the vapor in the air would be condensed into cloud much sooner than Mr. Espy supposed, and he thought it certain that the small amount of heat given out by the vapor would not suffice to expand the air in the funnel to the extent required, if Mr. Espy's views were correct.

To the first objection, Mr. Espy replied, that the objection was answered in the paper itself, in which it was shown that the air was calm all round the tornado, within a few hundred yards, and that it ought to be so on his principles.

To the second, he answered, that Mr. Redfield had laid down a test by which it could be ascertained with absolute certainty whether or not the air blew in towards the centre, and that was, that the trees in the central line of the path should be found lying parallel with the path; and he stated that this had been found to be the case in all the tornadoes which had been examined.

To the third, he answered, that if all the vapor should be condensed, as Professor Forbes thinks, then the effects produced would be much more violent. Professor Forbes would find that, if *all* the vapor which is in a mass of air when the dew-point is 73° (and it is sometimes higher than that when tornadoes occur) should be condensed, the latent caloric given out would heat the air more than 70° ; and in cases of hail, nearly 80° , by the addition of caloric of fluidity. Professor Forbes would find, by a rigid examination of the subject, that all the vapor is never condensed, because the dew-point, at great heights, falls by expansion faster than the temperature.

As to the question whether Mr. Redfield and Colonel Reid's theory of a whirl, or Mr. Espy's radial theory, was most accordant with fact, Mr. Osler said, that, from the investigation he had given this subject, he was convinced that the centripetal action described by Mr. Espy took place in most hurricanes. The particulars he, Mr. Osler, had collected, together with the indications obtained from the anemometers at Birmingham and Plymouth, satisfied him that the action of the great storm of the 6th and 7th of January, 1839, was not rotatory at the surface of the earth when it passed across England. He differed, however, both from Mr. Espy and Mr. Redfield, in one essential point, for he believed it would be almost impossible to have a violent hurricane without, at the same time, having both rotatory and centripetal action. A storm might very probably be generated in the first instance, in the manner accounted for by Mr. Espy, or by the action of contrary currents; in the first case, the rush of air towards a spot of greater or less diameter, would not be perfectly uniform, owing to the varying state of the surrounding atmosphere; this, together with the upward tendency of the current, would, in some cases, produce a violent eddy or rotatory motion, and a whirlwind of a diameter varying with the cause would ensue; the centripetal action would thus be immensely increased, the *whirlwind itself* demanding a vast supply of air, which would be constantly thrown off spirally upwards, and diffused over the upper atmosphere, thus causing the high state of the barometer which surrounds a storm. He further stated that he had brought his theory of the combined action of centripetal and rotatory motion before the meeting of this Association at Birmingham, and a short notice of it would be found in the reports of the Sections. If no

rotatory action takes place, he believed that we merely experienced the rush of air which necessarily precedes a heavy fall of rain or thunder storm; but he believed that nothing violent enough to be called a hurricane could take place, unless a violent rotatory or whirling action be first produced, and that in many and perhaps most cases the rotatory portion is not in contact with the earth.

Mr. Arch. Smith said there was one point which must not be overlooked in any correct comparison of the rival theories. From the principle of the conservation of areas, it was perfectly certain that if a storm was caused in the manner supposed by Mr. Espy, there must be a rotation, greater or less, in the centre. Because, unless the motion of all the currents was accurately directed to one point, or at least their *moments* in a horizontal plane were equal to zero, which was infinitely improbable, a motion of rotation must be the result, as in the instance of the motion of water in a funnel, cited by Mr. Espy.

If the central space of comparative rest were large, the whirl might be imperceptible; but if small, as in the case of a waterspout, it must be considerable. Without embracing either theory, he thought it difficult to conceive, as he understood Mr. Osler to do, the motion of rotation to be the primary, and the centripetal (which, indeed, would be centrifugal) force to be secondary phenomenon. But it was comparatively easy to suppose the centripetal motion to be the primary phenomenon, and quite certain that, if so, there must result a secondary phenomenon of rotation, of which, indeed, some indications appeared in Mr. Espy's maps.

In making some remarks on the preceding paper, Sir David Brewster observed that it was impossible to form any decided opinion on the subject, from the great want of well ascertained facts; and as Mr. Espy had founded his theory expressly on observations often made by himself, it was impossible to do justice to his ingenious views until a greater number of facts had been collected. The facts, too, stated by Mr. Espy were opposed to those observed by others. In the case of hurricanes or tornadoes, the convergency of the aerial currents in the one theory, and their rotatory motion in the other were not *observed*, but *inferred* from a number of facts; but as Mr. Espy regarded waterspouts as formed in the same manner as tornadoes, and as Colonel Reid had distinctly stated in his letter to Sir David, already referred to, that he had *actually seen*, from the government house in Bermuda, by means of a telescope, the *waterspout revolving like the hands on the dial plate of a watch*, there could be no doubt that we were at variance about facts. This explicit and distinct *observation* of a rotatory motion by so able and accurate an observer as Colonel Reid, was worth a thousand inferences. As to Sir David Brewster's objection, Mr. Espy thought his paper itself contained an answer to it, where he showed that bodies taken up on one side of the tornado would whirl one way, and bodies taken up on the other side would whirl the other. And it was worthy of notice that all Colonel Reid's spouts whirl from left to right, and all Mr. Redfield's from right to left, on this side of the equator. Mr. Espy had examined a great many witnesses of the Brunswick tornado, and some saw the materials which went up whirl one way, and some another, though they were standing together; and Professor Strong and Professor Beck, of New Brunswick, saw the materials whirl as the hands of a watch, contrary to the manner Mr. Redfield says this and all other spouts in this latitude whirl. Professor Phillips must say that he thought the statements of fact connected with tornadoes, as stated in the American journals, were more consistent with Mr.

Espy's than with Mr. Redfield's theory; and Colonel Reid thinking he saw rotation in a water-spout could not invalidate the abiding evidence from uprooted forests.

Mr. Espy stated that his experiments with a funnel are in opposition to the statement here made. He has performed many, and in all instances where care was taken to have the water still before removing the finger from the lower end, and letting the water run out, it discharged the whole contents without any whirling motion. The same occurred whether a funnel was used or a tub with a hole in the bottom. Mr. Espy acknowledges, however, Mr. Smith's doctrine of the conservation of areas to be correct, and he admits it as highly probable that spouts sometimes whirl one way and sometimes another, but generally neither way; and in all cases the whirl, if any, would only be perceptible very near the centre. He first supposed that all spouts whirled, and was only compelled to abandon this notion by the facts themselves.

NOTE 228.

Mean temperature of 305 places, according to Mahlmann.

PLACES.	Latitude.	Long. from Paris.	Height above sea.	MEAN TEMPERATURE—CENTIGRADE.				
				Year.	Winter.	Spring.	Summer.	Autumn.
Melville Island.....	74 47 N.	113 08 W.	.....	-18.7	-33.5	-19.5	2.8	-18.0
Ingloolik Island.....	69 19	83 23	.....	-16.6	-29.7	-16.8	1.7	-14.0
Ustjansk, (Siberia).....	70 55	136 04 E.	.....	-16.6	-38.4	-14.7	9.2	-23.9
Port Bowen.....	73 14	91 13 W.	.....	-15.8	-31.7	-21.0	2.7	-11.9
Boothia Felix.....	70 02	94 10	.....	-15.7	-33.2	-20.7	3.4	-12.4
Winter Iceland.....	66 11	85 31	.....	-14.0	-29.1	-14.2	1.7	- 8.0
Fort Enterprise.....	64 28	115 26	253	.....	-30.9	-13.2	.....	- 7.3
Jakontsk.....	62 01	126 33 E.	117	- 9.7	-38.9	- 8.3	17.2	- 6.6
Nova Zembla.....	73 00	51 30	.....	- 8.4	-19.0	-11.8	3.6	- 6.3
Fort Franklin.....	65 12	125 33 W.	68	- 8.2	-27.2	-10.0	10.2	- 6.0
Fort Reliance.....	62 46	109 01	107	.....	-29.1	-10.7	.....	.....
Spitzbergen.....	80 00	14 00 E.	.....	.....	.....	.....	3.4	.....
Sea of Greenland.....	78 00	7 00	.....	(- 7.7)	.....	- 9.4	1.4	.....
Nain, (Labrador).....	57 10	64 10 W.	.....	- 3.6	-18.5	- 5.8	7.6	2.2
Fort Simpson.....	62 11	123 52	78	- 3.5	-23.5	- 2.8	15.1	- 2.8
Enontekis, (Lapland).....	68 40	20 00	735	- 2.7	-17.0	- 3.9	12.6	- 2.7
Saint Bernard, (Hospital).....	45 50	4 45	2,494	- 1.0	- 7.8	- 2.0	6.1	- 0.4
Saint Gothard.....	46 33	6 14	2,095	- 0.8	- 7.6	- 2.7	6.7	0.0
Saltonst, (Ural).....	55 08	57 08	322	- 0.7	-16.6	0.8	15.2	0.2
Haapakyla, (Sweden).....	66 27	21 27	.....	- 0.5	-14.2	- 2.3	14.4	0.1
Irkontsk.....	52 16	101 58	409	- 0.2	-17.6	4.5	15.9	- 2.2
Eyafjordur.....	65 40	22 00	.....	0.0	- 6.2	- 2.2	7.7	1.4
Cape North, (Norway).....	71 10	23 30 E.	.....	0.1	- 4.6	- 1.3	6.4	- 0.1
Schneeekopp, (Silesia).....	50 44	0 00	1,600	0.2	.....	.....	8.1	.....
Uleaborg.....	65 03	23 06	.....	0.7	-11.1	- 2.7	14.3	- 2.2
Nijné Tagnilsk, (Ural).....	57 54	0 00	234	1.1	-15.5	5.4	19.8	5.4
Umea.....	63 50	17 56	.....	2.1	-10.2	0.6	14.1	3.1
Kasan.....	55 48	46 47	56	2.2	-14.3	2.6	17.0	2.8
Hernosand.....	62 38	15 33	.....	2.3	- 8.1	0.2	13.4	3.6
Petersburg.....	59 56	27 59	.....	3.5	- 8.4	1.7	15.7	4.7
Saint John, (Newfoundland).....	47 34	54 58 W.	43	3.5	- 4.9	0.2	12.2	6.5
Moscow.....	55 45	35 18 E.	146	3.6	-10.3	6.3	16.8	1.6
Reikiövig, (Iceland).....	64 08	24 16 W.	.....	4.0	- 1.6	2.4	12.0	3.3
Helsingfors.....	60 10	0 00	.....	4.0	- 6.1	1.4	15.2	5.7
Iluluk, (Russian America).....	53 52	168 45	.....	4.1	0.1	2.0	10.5	3.7
Falun, (Sweden).....	60 39	13 25 E.	121	4.4	- 5.5	3.2	14.6	5.3
Abo.....	60 27	19 57	.....	4.6	- 5.4	2.6	15.7	5.4
Tambow, (Russia).....	52 47	39 08	62	5.1	- 8.7	.....	18.4	.....
Port Famine.....	53 38 S.	73 14 W.	.....	.....	1.1	.....	.....	5.7
Upsal.....	59 52 N.	15 18 E.	.....	5.2	- 3.7	3.4	15.1	6.2
Sondmor, (Norway).....	62 30	4 00	.....	5.3	- 2.7	4.0	13.3	6.5
Christiania.....	59 54	8 25	.....	5.4	- 3.8	4.0	15.3	5.8
Eastport, (United States).....	44 54	69 16 W.	.....	5.4	- 5.4	3.6	16.1	7.6
Stockholm.....	59 21	15 43 E.	41	5.6	- 3.6	3.5	16.1	6.5
Pompey, (United States).....	42 56	78 25 W.	390	6.1	- 5.3	5.3	17.7	6.8
Koenigsburg.....	54 43	18 10 E.	.....	6.2	- 3.3	5.3	15.9	6.7
Tepl, (Convent).....	49 58	10 33	643	6.2	- 2.9	6.3	14.7	6.8
High Peyssenberg.....	47 48	8 41	957	6.2	- 1.6	5.4	14.4	6.5
St. Lawrence, (United States).....	44 40	77 20 W.	121	6.2	- 6.8	5.9	18.6	7.4
Halifax, (Nova Scotia).....	44 39	65 57	.....	6.2	- 4.4	2.9	17.2	9.0
Carlstadt, (Sweden).....	59 25	11 10 E.	53	6.3	- 2.7	4.7	16.2	6.9
Vilna.....	54 41	22 58	117	6.3	4.6	5.7	17.6	6.5
Montreal.....	45 31	75 55 W.	.....	6.5	- 8.1	6.8	20.6	8.4
Lead Hills, (Scotland).....	55 25	6 08	390	6.6	0.2	6.4	13.1	6.5
Hof, (Franconia).....	50 19	9 35 E.	487	6.6	- 1.5	5.8	15.9	6.2
Tegernsee, (Bavaria).....	47 42	9 25	735	6.6	- 1.9	5.7	15.3	7.3
Fort Snelling, (Mississippi).....	44 53	95 28 W.	240	6.6	- 9.8	8.2	21.3	7.2
Fort Howard, (Michigan).....	44 40	89 22	185	6.6	- 7.3	5.8	20.5	6.9
Tilsit, (Prussia).....	55 04	19 33 E.	.....	6.7	- 3.6	5.9	16.7	7.3

Mean temperature of 305 places—Continued.

PLACES.	Latitude.	Long. from Paris.	Height above sea.	MEAN TEMPERATURE—CENTIGRADE.				
				Year.	Winter.	Spring.	Summer.	Autumn.
Hohenelbe, (Bohemia).....	50 38 N.	13 14 E.	458	6.7	— 2.6	6.5	15.6	7.2
Hohenfurth, (Austria).....	48 37	12 00	555	6.7	— 3.3	7.2	16.4	6.0
Genkingen, (Sonabia).....	48 25	6 50	780	6.8	— 1.6	6.8	14.8	7.1
New Archangel.....	57 C3	137 38 W.	.....	6.9	0.7	5.2	12.7	8.6
Wexio, (Sweden).....	56 53	12 25 E.	146	6.9	— 2.3	5.3	17.7	7.1
Braunsberge, (Prussia).....	54 19	17 34	.....	6.9	— 3.8	6.0	15.8	7.4
Douvre, (United States).....	45 13	73 14 W.	.....	6.9	— 6.0	5.7	19.0	8.0
Concord, (United States).....	43 12	73 49	.....	6.9	— 5.2	6.7	18.5	7.6
Fayetteville, (United States).....	42 58	75 02	.....	7.0	— 5.6	6.0	19.0	7.9
Ullensvang, (Norway).....	60 19	4 20 E.	.....	7.2	— 0.1	6.0	15.6	7.4
Sund, (Sweden).....	55 42	10 51	.....	7.2	— 1.4	5.4	16.7	8.3
Freyberg, (Saxony).....	50 55	11 00	403	7.2	— 1.7	7.2	15.9	7.5
Alford, (Scotland).....	57 13	5 02 W.	127	7.3	1.9	6.0	13.7	7.4
Gotha.....	30 57	8 23 E.	308	7.3	— 1.3	7.3	15.5	7.6
Tabor, (Bohemia).....	49 24	12 19	429	7.3	2.7	7.3	16.9	7.7
Dunfermline, (Scotland).....	56 05	5 46 W.	.....	7.4	2.6	6.1	12.9	7.8
Applegarth-Manse, (Scotland).....	55 13	5 32	55	7.4	2.4	6.2	13.4	8.0
Utica, (United States).....	43 07	77 33 W.	146	7.4	4.0	6.7	19.0	8.4
Thorshavn, (Norway).....	62 02	9 6	.....	7.5	4.3	5.6	12.2	8.2
Warsaw.....	52 13	18 72 E.	121	7.5	2.5	7.0	17.5	8.0
Dantzick.....	54 21	16 18	.....	7.6	— 1.2	6.7	16.4	8.4
Zittan.....	50 54	12 28	247	7.6	— 1.7	7.5	16.5	8.3
Bayreuth.....	49 57	9 16	341	7.6	— 1.3	7.9	15.9	8.0
Wartenberg, (Poland).....	51 19	15 21	146	7.8	— 2.0	7.9	17.1	8.4
Kielec, (Poland).....	50 52	18 18	273	7.8	— 1.7	7.8	16.0	8.8
Kobourg.....	50 16	8 39	220	7.8	— 0.9	7.2	17.1	8.2
Kremsmunster, (Austria).....	43 03	11 48	360	7.8	— 1.9	8.0	17.1	8.2
Berne.....	46 57	5 06	585	7.8	— 0.9	7.7	15.8	8.5
Gothembourg.....	57 41	9 36	.....	7.9	— 0.3	6.5	16.9	8.7
Augsbourg.....	48 22	8 34	495	7.9	— 1.7	8.3	16.6	8.2
Stromness, (Orkneys).....	58 57	5 49 W.	.....	8.0	4.0	6.5	12.5	9.0
Praestoe, (Denmark).....	55 07	9 43 E.	.....	8.0	— 0.3	6.5	16.2	9.4
Cracow.....	50 04	17 37	201	8.0	— 3.3	6.9	19.1	8.0
Landskron, (Bohemia).....	49 55	14 17	331	8.0	— 2.3	8.3	17.7	8.1
Kinfauns Castle, (Scotland).....	56 24	5 39 W.	45	8.1	3.3	7.4	14.1	8.7
Breslau.....	51 06	14 42 E.	140	8.1	— 1.0	7.2	17.3	8.1
Clunie-Manse, (Scotland).....	57 12	4 55 W.	58	8.2	— 3.2	7.9	14.8	7.9
Copenhagen.....	55 41	10 14 E.	.....	8.2	— 0.4	6.5	17.2	9.3
Stralsund.....	54 19	10 45	.....	8.2	— 0.2	7.0	16.5	9.3
Medfield, (United States).....	42 15	73 20 W.	.....	8.2	— 3.0	6.8	19.6	9.4
Apenrade, (Germany).....	55 05	7 05 E.	.....	8.3	0.6	6.9	16.2	9.0
Kendal, (England).....	54 17	5 06 W.	43	8.3	2.9	7.5	14.5	8.5
Alderly Rectory.....	53 20	4 40	.....	8.3	2.7	7.6	14.0	8.9
Arnstadt, (Germany).....	50 50	8 37 E.	292	8.3	— 1.3	8.5	17.2	8.9
Fulda.....	50 34	7 24	273	8.3	— 2.6	8.1	18.7	8.9
Carlisle.....	54 54	5 17 W.	.....	8.4	3.0	7.5	14.2	8.7
Giengen.....	48 37	7 55 E.	481	8.4	0.0	8.9	17.0	8.0
Swinemunde.....	53 51	11 57	.....	8.5	— 0.7	7.4	17.4	9.5
Dresden.....	51 03	11 24	121	8.5	— 0.4	8.4	17.2	8.4
Jena.....	50 56	9 17	162	8.5	— 0.7	8.9	16.5	9.1
Saint Gall.....	47 26	7 02	.....	(8.5)	0.0	7.7	(17.2)	8.9
Edinburgh.....	55 57	5 32 W.	88	8.6	3.6	7.6	14.4	8.9
Cuxhaven.....	53 53	6 24 E.	.....	8.6	0.3	7.5	17.2	9.2
Hamburg.....	53 33	7 38	.....	8.6	0.3	8.0	17.0	8.8
Berlin.....	52 31	11 03	39	8.6	— 0.8	8.0	17.3	8.8
Ratisbon.....	49 01	9 46	335	8.6	— 1.4	9.4	17.9	8.7
Tubigen.....	48 31	6 43	331	8.6	— 0.2	8.6	17.1	8.9
New Malton, (England).....	54 08	3 07 W.	.....	8.7	2.5	.....	15.1	.....
Manchester.....	53 29	4 35	47	8.7	2.8	7.9	14.8	9.2
Andover, (United States).....	42 38	73 27	58	8.7	— 2.9	7.2	20.6	9.6
Sagan, (Silesia).....	51 39	12 59 E.	123	8.8	— 2.6	7.0	18.2	8.2
Halle.....	51 31	9 37	111	8.8	0.0	8.6	17.5	9.1

Mean temperature of 305 places—Continued.

PLACES.	Latitude.	Long. from Paris.	Height above sea.	MEAN TEMPERATURE—CENTIGRADE.				
				Year.	Winter.	Spring.	Summer.	Autumn.
Saaz, (Bohemia).....	50 20 N.	11 13 E.	257	8.8	-1.4	9.1	18.3	9.1
Andechs, (Germany).....	47 58	8 52	702	8.8	-1.2	8.8	18.6	9.1
Bremen.....	53 05	60 27	.....	8.9	-0.5	8.3	17.2	9.5
Munich.....	48 09	9 14	526	8.9	-0.4	9.0	17.4	9.1
Salem, (United States).....	42 31	73 14 W.	.....	8.9	-2.6	7.2	20.6	10.5
Cambridge, (United States).....	42 22	73 28	.....	8.9	-2.8	7.4	20.7	10.1
Erfurt.....	50 59	8 42 E.	209	9.0	0.6	8.5	17.3	9.5
Innsbruck.....	47 16	9 03	590	9.0	-1.9	10.0	18.3	9.6
Gottingen.....	51 32	7 36	132	9.1	0.6	.....	17.6	.....
Wangen, (Germany).....	48 46	6 55	277	9.1	0.4	9.3	17.9	9.4
Rochester, (United States).....	43 08	80 11 W.	156	9.1	-2.5	8.5	20.3	10.2
Albany, (United States).....	42 39	76 05	39	9.2	-3.0	8.7	20.9	9.7
Salzufflen, (Germany).....	52 5	6 25 E.	97	9.3	1.5	8.9	17.3	9.6
Elberfeld.....	51 16	4 49	131	9.3	2.2	8.8	16.3?	9.7
Nicolaieff, (Crimea).....	46 58	29 39	.....	9.3	-3.4	9.6	21.8	10.0
Boston.....	42 21	73 24 W.	.....	9.3	-1.6	7.7	20.5	10.4
Dublin.....	53 25	8 41	.....	9.5	4.6	8.4	15.3	9.8
Munster.....	51 28	5 18 E.	63	9.5	2.2	8.7	16.8	10.1
Prague.....	50 5	12 06	191	9.5	-0.4	9.6	18.9	9.8
Lausanne.....	46 31	4 18	501	9.5	0.5	9.2	18.4	9.9
Zwanenburg, (Holland).....	52 15	2 00	.....	9.6	2.6	8.4	16.9	10.6
Bushey Heath, (England).....	51 38	0 00 E.	169	6.6	3.1	8.7	16.6	10.2
Tottenham-green, near London.....	51 31	2 26 W.	.....	9.6	3.1	9.0	16.4	10.0
Stuttgart.....	48 46	6 51 E.	248	9.6	0.8	10.0	17.8	9.7
New Bedford, (United States).....	41 38	73 16 W.	.....	9.6	-0.8	7.7	20.1	11.5
Leyden.....	52 10	2 09 E.	.....	9.7	2.4	8.4	17.2	10.5
Cheltenham, (England).....	51 55	4 24 W.	.....	9.7	3.8	9.2	15.8	10.1
Geneva.....	46 12	3 49 E.	396	9.7	1.2	9.5	17.9	10.2
St. John of Maurienne.....	45 18	4 04	546	9.7	0.2	10.0	18.7	9.8
Simperopol, (Crimea).....	45 00	31 50	259	9.7	0.5	10.6	19.6	8.0
Council Bluffs, (United States).....	41 25	98 03 W.	244	9.7	-5.2	10.6	23.2	10.3
Frankfort-on-the-Main.....	50 07	6 21 E.	117	9.8	1.2	9.9	18.3	10.0
Strasbourg.....	48 35	5 25	146	9.8	1.1	10.0	18.1	10.0
Basle.....	47 34	5 15	253	9.8	0.4	9.8	18.4	9.7
Haarlem.....	52 23	2 18	.....	10.0	2.8	9.2	17.0	11.0
Treves.....	49 46	4 18	156	10.0	1.9	10.0	17.8	10.1
Maestricht.....	50 51	3 21	49	10.1	1.9	10.0	18.0	11.1
Wurtzburg.....	49 48	7 36	172	10.1	1.6	10.2	18.7	9.7
Vienna.....	48 13	14 03	156	10.1	0.2	10.5	20.3	10.3
Fort George, (America).....	46 18	125 20 W.	.....	10.1	3.8	9.0	15.5	12.0
Fort Wolcott, (United States).....	41 29	73 40	.....	10.1	-0.1	8.4	20.6	12.2
Brussels.....	50 51	2 02 E.	58	10.2	2.5	10.1	18.2	10.2
Carlsruhe.....	49 01	6 05	113	10.2	1.1	10.4	18.9	10.2
Mannheim.....	49 29	6 08	92	10.3	1.5	10.4	19.5	9.8
Buda.....	47 30	16 43	156	10.3	-0.6	10.4	21.1	10.5
London.....	51 31	2 26 W.	.....	10.4	4.2	9.5	17.1	10.7
Lyme-Regis.....	50 43	5 16	.....	10.4	5.5	9.2	15.2	11.6
Erasmus Hall, (United States).....	40 37	76 18	.....	10.7	0.4	9.3	21.3	11.8
Paris.....	48 50	0 2	64	10.8	3.3	10.3	18.1	11.2
Montmorency.....	49 00	0 03	140	10.9	2.8	10.6	18.7	11.4
Gosport, (England).....	50 48	3 26	.....	11.0	5.0	10.1	17.1	11.9
Plymouth.....	50 22	6 28	.....	11.1	6.9	10.1	10.0	11.7
Penzance.....	50 07	7 53	.....	11.1	6.6	9.9	16.5	12.1
Fort Columbus, (United States).....	40 42	76 29	.....	11.2	-0.1	9.9	22.5	12.6
Hobarttown, (Island of Dieman).....	42 45 S.	145 15 E.	.....	11.3	5.6	11.6	17.3	10.9
Germantown, (United States).....	40 03 N.	77 37 W.	62	11.3	0.0	10.3	22.8	12.1
Fort Vancouver, (America).....	45 38	122 34	.....	11.5	4.2	11.0	18.2	12.9
Sevastopol.....	44 36	31 12 E.	49	11.5	1.8	10.2	21.7	12.6
La Rochelle.....	46 09	3 28 W.	.....	11.6	4.2	10.6	19.4	11.5
Marietta, (United States).....	39 25	83 50	195?	11.6	0.8	12.3	21.9	11.6
Baltimore.....	39 17	78 58	.....	11.6	0.4	10.4	23.1	12.9
Turin.....	45 04	5 22 E.	279	11.7	0.8	11.7	22.0	12.1

Mean temperature of 305 places—Continued.

PLACES.	Latitude.	Long. from Paris.	Height above sea.	MEAN TEMPERATURE—CENTIGRADE.				
				Year.	Winter.	Spring.	Summer.	Autumn.
Darjiling, (India)	27 00 N.	86 04 E.	2,124	12.0	5.4	12.5	16.3	13.3
Middletown, (United States)	42 24	76 33 W.	.....	12.1	2.2	11.3	21.1	13.6
Cincinnati	39 06	86 47	162	12.2	0.5	12.4	22.8	12.8
Padona	45 24	9 32 E.	.....	12.5	2.8	12.1	21.9	13.0
Pavia	45 11	6 49	88	12.7	2.2	12.6	22.8	13.2
Peking	39 54	114 09	97	12.7 ?	-3.2 ?	13.5	28.1 ?	12.4
Washington	38 53	79 22 W.	.....	12.7	2.3	10.2	21.7	13.5
Milan	45 28	6 51 E.	146	12.8	2.1	13.0	22.7	13.2
Toulouse	43 36	0 54 W.	152	12.9	5.2	11.8	19.9	13.9
Saint Louis, (Missouri)	38 36	91 56	170	13.0	0.7	12.9	24.1	14.4
Trieste	45 39	11 26 E.	88	13.2	4.1	12.1	21.9	13.7
Sienna	43 03	9 00	325	13.4	5.2	12.4	21.7	14.0
Brescia	45 33	7 54	152	13.5	3.7	13.9	22.4	14.0
Venice	45 26	10 00	.....	13.7	3.3	12.6	22.8	13.3
Constantinople	41 00	26 39	.....	13.7	4.8	11.0	23.0	15.8
Bordeaux	44 50	2 55 W.	.....	13.9	6.1	13.4	21.7	14.4
Mafrá	38 56	11 41	228	13.9	9.6	12.7	18.2	15.1
Otacamound, (India)	11 55	74 30 E.	2,241	13.9	11.4	16.3	14.1	13.8
Missouri	30 27	75 42	1,910	14.0	5.5	15.9	19.8	14.8
Montpellier	43 36	1 32	.....	14.1	6.9	13.8	24.4	16.1
Marseilles	43 18	3 02	45	14.1	6.9	12.9	21.4	14.7
Bologne	44 30	9 01	82	14.2	2.8	14.5	25.2	14.3
Camajore	43 55	8 00	.....	14.2	6.7	13.6	21.9	14.8
Madrid	40 25	6 2	663	14.2	5.6	14.2	23.4	13.7
Avignon	43 27	2 28	.....	14.4	5.8	13.9	23.1	14.6
Cascina, (Tuscany)	43 40	8 10 E.	.....	14.6	6.8	13.7	22.5	15.1
Lucques	43 51	8 10	.....	14.9	4.6	16.1	23.6	15.3
Santa Fe de Bogota	4 36	76 34 W.	2,631	15.0	15.1	15.3	15.3	14.5
Toulon	43 07	3 36 E.	.....	15.1	8.6	13.3	22.3	16.3
Lohonghat, (India)	29 23	79 56	1,696	15.2	7.5	15.4	21.7	16.3
Florence	43 47	8 55	64	15.3	6.8	14.7	24.0	15.7
Rome	41 54	10 08	53	15.4	8.1	14.1	22.9	16.5
Perpignan	42 42	0 34	53	15.5	7.2	14.4	23.9	16.2
Nice	43 42	4 57	.....	15.6	9.3	13.3	22.5	17.2
Quito	0 14 S.	81 05 W.	2,914	15.6	15.4	15.7	15.6	17.5
Capodi Monte, near Naples	40 52 N.	11 55 E.	150	15.7	8.7	14.3	23.5	16.3
Chapel Hill, (United States)	35 54	81 19 W.	.....	15.7	5.4	15.4	25.2	16.7
Cagliari	39 13	4 06 E.	101	16.3	10.2	14.0	22.4	18.3
Naples	40 51	11 55	55	16.4	9.8	15.2	23.8	16.8
Lisbon	38 42	11 29 W.	72	16.4	11.3	15.5	21.7	17.0
Mexico	19 26	101 26	2,271	16.6	13.0	18.1	19.1	16.2
Buenos Ayres	34 37	60 44	.....	16.9	11.4	15.2	22.8	18.1
Barcelona	41 22	0 09	.....	17.0	10.0	15.5	24.5	17.8
Laguna	28 30	18 39	546	17.1	13.6	15.4	20.2	18.9
Palermo	38 07	11 01 E.	55	17.2	11.4	15.0	23.5	19.0
Constantine	36 20	4 14	.....	17.2	10.2	12.3	26.6	19.7
Kathmandon	27 42	85 20	1,413	17.3	8.4	18.4	24.3	18.2
Abbeville, (Carolina)	34 10	84 46 W.	.....	17.5	8.3	18.7	26.7	16.3
Algiers	36 47	0 43	.....	17.8	12.4	17.2	23.6	21.4
Gibraltar	36 07	7 41	.....	17.9	13.8	17.3	22.7	17.8
Nicolosi, (Sicily)	37 35	12 46 E.	706	18.0	10.7	16.6	25.9	18.7
Canée, (Candia)	35 29	21 40	.....	18.0	12.4	15.6	25.2	18.9
Paramatta, (New Holland)	33 50 S.	148 50	.....	18.1	12.5	19.2	23.3	18.2
Savannah, (United States)	32 05 N.	83 27 W.	.....	18.1	10.9	18.0	25.1	18.3
Smyrna	38 26	24 48 E.	.....	18.2	11.1	14.6	26.0	21.1
Nangasaki, (Japan)	32 45	127 32	.....	18.3	8.4	15.5	27.7	21.6
Natchez, (United States)	31 34	93 45 W.	58	18.3	10.0	19.1	25.4	18.6
Funchal, (Madeira)	32 38	19 15	.....	18.7	16.3	17.5	21.1	19.8
Messina	38 11	13 14 E.	.....	18.8	12.8	16.4	25.1	20.7
Ville du Cap	33 55	16 08	.....	19.1	14.8	18.6	23.4	19.4
Montevideo	34 54 S.	58 33 W.	.....	19.3	14.1	18.1	25.2	20.0
Smithville, (United States)	34 00 N.	80 25	.....	19.3	11.4	18.9	26.7	20.1

Mean temperature of 305 places—Continued.

PLACES.	Latitude.	Long. from Paris.	Height above sea.	MEAN TEMPERATURE—CENTIGRADE.				
				Year.	Winter.	Spring.	Summer.	Autumn.
New Orleans	29 58 N.	92 37 W.	.....	19.4	11.8	18.9	26.5	20.4
Catana	37 30	12 40 E.	.....	19.6	12.6	17.5	26.9	21.4
Saint George, (Bermuda).....	32 20	67 10 W.	.....	19.7	15.1	17.6	24.0	22.2
Baton Rouge, (United States)	30 26	93 25	.....	19.7	11.7	20.2	27.0	19.9
Jesup, near Natchitoches	31 30	96 09	53	20.2	11.8	20.7	28.3	19.8
Tunis	36 48	7 51 E.	.....	20.3	13.2	18.3	28.3	21.9
Clinch Cant.	30 24	89 34 W.	.....	20.4	12.0	21.1	28.8	20.7
Fort St. Philippe, (Louis)	29 29	91 41	.....	20.8	12.4	21.4	28.3	22.6
Fernandina, (Florida).....	30 35	84 55	.....	21.1	15.7	21.1	26.1	21.7
Canton	23 08	110 56 E.	.....	21.0	12.7	21.0	27.8	22.7
Las Palmas, (Canaries)	28 00	17 51 W.	.....	21.8	18.0	19.4	23.8	26.2
Sainte Croix de Tenerife	28 28	18 36	.....	21.9	18.1	21.3	24.9	23.4
Fort King, (Florida)	29 03	84 30	.....	22.0	16.5	21.4	28.1	21.7
Caracas, (Venezuela).....	10 31	69 25	887	22.0	20.9	21.8	23.4	22.2
Ste. Augustine, (Florida).....	29 48	83 55	.....	22.3	15.3	21.9	28.2	24.0
Cairo.....	30 02	28 55 E.	.....	22.4	14.7	22.0	29.2	23.5
Serampore, (India)	29 57	75 23	308	22.4	12.2	24.8	30.0	22.4
Cant. Booke, (Florida).....	27 57	84 55 W.	.....	22.4	16.2	22.7	26.7	24.0
Macao	22 11	111 14 E.	.....	22.5	16.4	21.1	28.3	24.1
Kandy, (Ceylon).....	7 18	78 30	513	22.7	22.3	23.5	22.8	22.4
Ambala, (India).....	30 25	74 25	331	22.8	13.2	25.4	30.1	22.6
Ubajay, (Havana).....	23 00	84 45	94	23.0	18.3	21.7	28.4	23.9
Rio Janeiro.....	22 55 S.	45 36 W.	.....	23.1	20.3	22.5	26.1	23.6
Honolulu, (Sandwich Islands).....	21 19	160 21	.....	23.7	21.6	23.0	25.5	24.8
Nasirabad, (India).....	26 18 N.	72 25 E.	458	24.5	15.6	27.6	30.0	24.7
Saint Louis, (Senegal)	16 01	18 53 W.	.....	24.6	21.1	21.4	27.6	28.2
Key West, (Florida).....	24 34	84 13	.....	24.7	21.5	24.2	27.9	25.5
Port Louis, (Maurice island).....	20 10 S.	55 08 E.	.....	24.9	21.6	23.8	28.1	26.0
Punah, (India).....	18 30 N.	72 00	546	24.9	21.5	26.7	26.1	25.3
Abouchehr.....	28 15 N.	48 34	.....	25.0	16.5	25.8	33.3	26.5
Fouttigurk, (India).....	27 22	77 11	181	25.0	15.3	28.5	31.7	24.5
Havana.....	23 09	84 43 W.	.....	25.0	22.6	24.6	27.4	25.6
Saint Denis, (Bourbon).....	20 52 S.	53 10 E.	43	25.0	22.6	24.9	26.7	25.6
Vera Cruz.....	19 12 N.	98 29 W.	.....	25.0	21.5	25.0	27.5	26.0
Seragapatam, (India).....	12 45	74 21 E.	735	25.1	22.9	28.5	24.5	24.4
Benares, (India).....	25 19	80 35	97	25.4	11.3	30.0	29.6	24.1
Matanzas, (Cuba).....	23 02	83 58 W.	35	25.5	22.5	25.8	27.6	26.2
Ava.....	21 40	113 40 E.	98	25.7	20.4	27.7	28.7	26.2
Calcutta.....	22 35	86 00	.....	25.8	19.9	28.1	28.5	26.1
Bombay.....	18 56	70 34	.....	26.0	23.2	27.2	28.1	27.3
Jamaica.....	17 50	79 02 W.	253	26.1	24.6	25.7	27.4	26.6
Tortola, (Antilles)	18 27	67 00	487	26.2	(25.5)	(25.2)	27.0	26.8
Kobbe, (Africa).....	14 11	25 48 E.	.....	26.5	(19.9)	28.7	30.0	27.4
Paramaribo, (Guiana).....	5 45	57 33 W.	.....	26.5	25.9	26.3	26.9	28.2
Singapour, (Malacca).....	1 17	101 30 E.	.....	26.5	25.9	26.9	27.1	26.7
St. Bartholomew, (Antilles).....	17 53	65 20 W.	.....	26.6	26.1	26.6	27.4	26.4
Batavia.....	6 09 S.	104 33 E.	.....	26.8	26.2	26.8	27.2	27.1
Fort Dundas, (Melville island).....	11 25	127 45 W.	.....	27.0	24.0	27.5	28.8	27.8
Anjarakandy, (India).....	11 40 N.	73 20 E.	.....	27.2	26.9	29.0	26.1	26.7
Christiansborg, (Africa)	5 24	2 10 W.	.....	27.2	27.4	29.0	25.5	27.0
St. Louis de Marankas.....	2 31 S.	46 36	.....	27.2	27.0	27.0	26.9	26.4
Cumana.....	10 28 N.	66 30	.....	27.4	27.0	28.6	28.1	.....
Trinconmale, (Ceylon).....	8 34	79 02	.....	27.4	25.7	28.4	28.9	27.2
Coast of Guinea.....	5 30	2 00	273	27.4	28.1	28.3	26.4	27.0
Nagpour, (India)	21 09	76 51 E.	.....	27.5	22.7	32.9	28.2	26.4
Madras.....	13 05	77 57	351	27.8	24.8	28.6	30.2	27.5
Konka, (Africa).....	13 10	12 10	.....	28.2	23.8	32.6	29.0	27.2
Karikal, (India).....	10 55	77 24	.....	28.7	26.4	30.0	29.9	28.6
Rio Hacha.....	11 28	75 20 W.	.....	.....	27.6	28.5	.....	.....
Maracaibo.....	11 19	76 29	.....	29.0	27.8	29.5	30.4	29.5
Massawah.....	15 36	37 09 E.	.....	(31.0)	26.7	29.5	.....	32.0

NOTE 229.

The following mean temperatures are taken from the Army Meteorological Register of 1855.

PLACES.	N. Lat.	W. Long.	Altitude above the sea.	Spring.	Summer.	Autumn.	Winter.	Year.	No. of years and parts of years observed.	
	° ' "	° ' "							Years.	Pt's yr's.
Fort Kent, Maine.....	47 15 00	68 35 00	575	35.22	61.68	39.88	11.36	37.04	1	3
Fort Fairfield, Maine.....	46 46 00	67 49 00	415	36.29	61.58	40.30	14.28	38.11	1	1
Hancock Barracks, Maine.....	46 07 00	67 49 00	620	39.15	63.33	43.15	16.41	40.51	16	1
Fort Sullivan, Maine.....	44 54 00	66 58 00	70	40.15	60.50	47.52	23.90	43.02	20	5
Fort Preble, Maine.....	43 39 00	70 20 00	20	42.77	65.24	48.16	24.70	45.22	16	5
Fort Constitution, New Hampshire.....	43 04 00	70 49 00	40	43.22	64.38	49.05	26.60	45.81	21	6
Fort Independence, Boston Harbor.....	42 20 00	71 00 00	50	46.02	68.58	52.45	28.63	48.92	12	6
Watertown Arsenal, Massachusetts.....	41 21 00	71 09 00	.....	44.63	68.12	49.38	27.22	47.34	5	1
Fort Adams, Rhode Island.....	41 29 00	71 20 00	40	45.55	69.46	53.56	30.22	49.70	8	3
Fort Wilcott, Newport Harbor.....	41 30 00	71 20 00	20	46.22	68.41	53.52	34.73	50.72	14	.....
Fort Trumbull, Connecticut.....	41 21 00	72 06 00	23	46.41	69.27	52.86	29.92	49.62	8	4
Fort Columbus, New York Harbor.....	40 42 00	74 01 00	23	48.74	72.10	54.55	31.38	51.69	33	.....
Fort Hamilton, New York Harbor.....	40 37 00	74 02 00	25	46.73	71.35	55.79	32.29	51.54	12	.....
West Point, New York.....	41 23 00	74 00 00	167	48.72	71.33	53.19	29.69	50.73	30	1
Watervliet Arsenal, New York.....	42 43 00	73 43 00	50 ?	46.19	70.92	50.55	24.64	48.07	30	1
Plattsburg Barracks, New York.....	44 41 00	73 25 00	186	42.34	66.76	46.67	20.22	40.00	8	4
Madison Barracks, Sackett's Harbor.....	43 57 00	76 15 00	262	44.26	67.77	49.34	24.16	46.38	8	8
Fort Ontario, New York.....	43 20 00	76 40 00	250	43.70	66.92	50.39	24.73	46.44	7	3
Fort Niagara, New York.....	43 18 00	79 08 00	250	44.83	68.41	50.59	27.81	47.91	11	5
Buffalo Barracks, New York.....	42 53 00	78 58 00	660	42.73	66.93	47.92	27.42	46.25	4	1
Alleghany Arsenal, Pittsburg, Pennsylvania..	48 32 00	80 02 00	704	49.97	71.47	51.43	30.59	50.86	21	1
Carlisle Barracks, Pennsylvania.....	40 12 00	77 14 00	500	49.76	72.15	52.05	30.45	51.10	10	5
Fort Mifflin, Pennsylvania.....	39 53 00	75 13 00	20	50.83	74.42	56.67	33.50	53.85	8	3
Fort Delaware, Delaware.....	39 35 00	75 34 00	10	53.55	75.91	58.50	36.28	56.06	4	3
Fort McHenry, Maryland.....	39 17 00	71 35 00	36	52.70	74.32	56.20	34.24	54.36	23	1
Fort Severn, Maryland.....	38 58 00	76 27 00	20	53.79	75.31	57.76	34.82	55.42	6	2
Washington City, District of Columbia.....	38 53 39	77 02 48	50 to 90	55.77	76.33	56.43	36.05	56.14	12	1
Fort Washington, Maryland.....	38 43 00	77 06 00	60	57.43	77.77	58.93	37.36	57.87	8	7
Bellona Arsenal, Richmond, Virginia.....	37 20 00	77 25 00	120	57.39	77.89	60.41	41.38	59.27	4	6
Fort Monroe, Virginia.....	37 00 00	76 18 00	8	56.87	76.57	61.68	40.45	58.89	30	.....
Fort Macon, North Carolina.....	34 41 00	76 40 00	20	59.46	78.51	65.19	45.75	62.23	3	3
Fort Johnston, North Carolina.....	34 00 00	78 05 00	20	64.46	80.19	67.46	50.60	65.68	13	5
Augusta Arsenal, Georgia.....	33 28 00	81 53 00	600 ?	64.37	80.21	63.37	48.07	64.01	17	4
Fort Moultrie, South Carolina.....	32 45 00	79 51 00	25	65.85	80.59	68.11	51.76	66.58	22	6
Oglethorpe Barracks, Georgia.....	32 05 00	81 07 00	40	67.08	80.70	67.94	54.06	67.44	5	4
Fort Marion, St. Augustine, Florida.....	29 48 00	81 35 00	25	68.54	80.27	71.53	58.08	69.61	13	12
Fort Shannon, Pilatka, East Florida.....	29 34 00	81 48 00	25	70.62	80.56	70.20	57.18	69.64	4	4
Picolata and Fort Heileman, Florida, and Fort Henderson, Georgia.....	29 48 00	80 45 00	.....	70.08	80.61	72.23	54.90	69.46	1	7
New Smyrna, East Florida.....	28 54 00	81 02 00	20	71.80	79.14	62.43	63.22	69.17	1	3
Fort Pierce, (Capron,) East Florida.....	27 30 00	80 20 00	30	73.44	81.30	74.80	63.27	73.20	4	4
Fort Dallas, East Florida.....	25 55 00	80 20 00	20	74.66	81.50	76.27	66.58	74.75	1	4
Key West, Florida.....	24 32 00	81 48 00	10	75.79	82.51	78.23	69.53	76.51	10	8
Fort Myers, South Florida.....	26 38 00	82 00 00	50	75.39	82.41	77.00	65.36	75.04	4	.....
Fort Brooke, Tampa Bay, Florida.....	28 00 00	82 28 00	20	72.06	80.20	73.08	62.35	71.92	11	3
Fort Meade, Florida.....	28 01 00	82 00 00	80	71.87	79.34	73.82	60.90	71.48	2	2
Fort Micanopy, Florida.....	29 30 00	82 28 00	68 ?	72.02	79.55	69.80	58.98	70.09	4	1
Fort King, Florida.....	29 10 00	82 10 00	50	70.72	80.22	70.64	58.41	70.00	5	5
Cedar Keys, Florida.....	29 07 00	83 03 00	35	70.08	79.07	71.04	58.22	69.60	2	1
Fort Wacassassa, Florida.....	.....	.....	.....	70.28	78.87	69.29	57.45	68.97	2	1
Fort Fanning, Florida.....	29 35 00	83 00 00	50	71.11	80.96	71.07	57.66	70.20	2	1
Forts Pleasant and Gamble, Middle Florida..	.....	.....	.....	71.52	79.35	68.36	56.91	69.04	1	4
Fort Barrancas, Pensacola, Florida.....	30 18 00	87 27 00	20	68.59	81.57	69.86	54.92	68.74	10	8
Fort Morgan, Alabama.....	30 14 00	88 00 00	20	64.35	80.33	69.17	53.68	66.88	.....	4
Mount Vernon Arsenal, Alabama.....	31 12 00	88 02 00	200 ?	67.02	78.82	65.81	51.72	65.84	11	4
Bay of St. Louis, Pass Christian, and East Pascagoula, Mississippi.....	.....	.....	.....	.....	82.14	69.71	.....	.....	.....	12
Fort Pike, Louisiana.....	30 10 00	89 38 00	10	69.97	82.84	70.83	55.80	69.86	10	9
Fort Wood, Louisiana.....	30 08 00	89 51 00	20	69.66	82.03	69.90	55.41	69.25	4	4
New Orleans, Louisiana.....	29 57 00	90 00 00	10	69.94	82.27	70.71	56.53	69.86	8	16

TABLE—Continued.

PLACES.	N. Lat.	W. Long.	Altitude above the sea.	Spring.	Summer.	Autumn.	Winter.	Year.	No. of years and parts of years observed.	
									Years.	Pt's yr's.
Forts St. Philip and Jackson, Louisiana.....	29 25 00	89 30 00	Sea level.	70.78	82.14	72.17	59.53	71.15	1	7
Baton Rouge, Louisiana.....	30 26 00	91 18 00	41	68.94	81.21	68.21	54.21	68.14	16	12
Fort Jesup, Louisiana.....	31 33 00	93 32 00	80 ?	66.85	81.27	66.22	51.00	66.34	22	1
Fort Towson, Indian Territory.....	34 00 00	95 33 00	300 ?	62.39	79.16	61.27	43.92	61.69	15	6
Fort Washita, Indian Territory.....	34 14 00	96 38 00	645	62.16	79.29	63.25	44.14	62.21	12	....
Fort Smith, Arkansas.....	35 23 00	94 29 00	460	61.29	77.60	60.08	41.11	60.02	10	2
Fort Gibson, Indian Territory.....	35 47 00	95 10 00	560	61.04	79.41	61.66	41.13	60.81	27	1
Fort Scott, Missouri.....	37 45 00	94 35 00	1,000 ?	54.78	74.95	55.27	32.99	54.50	10	1
Jefferson Barracks, Missouri.....	38 28 00	90 15 00	472	56.15	76.19	55.63	33.85	55.46	23	.5
St. Louis Arsenal, Missouri.....	38 40 00	90 05 00	450	54.15	76.19	55.44	32.27	54.51	12	.....
Newport Barracks, Kentucky.....	39 05 00	84 29 00	500	54.52	75.00	56.24	35.27	55.26	7	1
Detroit, Michigan.....	42 20 00	82 58 00	580	45.89	67.60	48.67	26.84	47.25	11	3
Fort Gratiot, Michigan.....	42 45 00	82 23 00	538	43.68	66.70	49.07	25.70	46.29	14	6
Fort Mackinac, Michigan.....	45 51 00	84 33 00	728	36.73	61.97	43.85	20.03	40.65	21	4
Fort Dearborn, Chicago, Illinois.....	41 52 00	87 35 00	591	44.90	67.33	48.85	25.90	46.75	4	1
Fort Brady, Michigan.....	46 30 00	84 43 00	600	37.60	62.01	43.54	18.31	40.37	26	5
Fort Wilkins, Michigan.....	47 30 00	88 00 00	620	38.47	68.80	42.96	21.78	41.00	1	2
Fort Howard, Wisconsin.....	44 30 00	88 05 00	620	43.52	68.51	46.01	19.91	44.49	20	2
Fort Winnebago, Wisconsin.....	43 31 00	89 28 00	770 ?	45.49	67.96	45.96	19.78	44.80	13	4
Fort Crawford, Wisconsin.....	43 05 00	91 00 00	642	48.66	72.28	48.34	21.25	47.63	17	3
Fort Armstrong, Illinois.....	41 30 00	90 40 00	528	50.53	74.12	51.73	24.88	50.31	11	1
Fort Atkinson, Iowa.....	43 00 00	92 00 00	700 ?	46.63	68.62	46.13	20.62	45.50	4	1
Fort Des Moines, Iowa.....	41 32 00	93 38 00	780	51.51	71.55	47.05	28.87	49.74	1	3
Fort Gaines, Minnesota.....	46 19 00	94 19 00	1,130	39.33	64.94	42.91	10.01	39.80	4	3
Fort Snelling, Minnesota.....	44 53 00	93 10 00	820	45.57	76.64	45.89	16.07	44.54	34	3
Fort Leavenworth, Kansas.....	39 21 00	94 44 00	896	53.78	74.05	53.66	29.64	52.78	23	3
Council Bluffs, Nebraska.....	41 30 00	95 48 00	1,250	49.28	74.76	51.36	21.73	49.28	6	1
Fort Kearny, Nebraska.....	40 38 00	98 57 00	2,360	46.81	71.47	49.35	23.04	47.67	5	2
Fort Laramie, Nebraska.....	42 12 00	104 47 00	4,519	46.84	71.94	50.32	31.14	50.06	5	2
Fort Arbuckle, Indian Territory.....	34 27 00	97 09 00	1,000 ?	61.67	78.71	62.17	40.78	60.83	4	2
Fort Belknap, Texas.....	33 08 00	98 48 00	1,600 ?	64.90	80.95	65.15	44.98	63.99	3	2
Fort Worth, Texas.....	32 40 00	97 25 00	1,100 ?	63.11	80.43	65.37	45.25	63.54	3	2
Phantom Hill, Clear Fork of Brazos, Texas...	32 30 00	99 45 00	2,300 ?	65.45	79.56	63.76	46.16	63.73	2	2
Fort Chadbourne, Texas.....	31 38 00	100 40 00	2,120	64.35	76.77	62.55	45.87	62.38	2	2
Fort Graham, Texas.....	31 56 00	97 26 00	900 ?	64.99	82.43	66.86	48.75	65.76	2	2
Fort Gates, Texas.....	31 26 00	97 49 00	1,000 ?	64.79	82.31	67.80	49.58	66.12	2	1
Fort Croghan, Texas.....	30 40 00	98 31 00	1,000 ?	65.86	80.65	66.98	49.46	65.74	3	2
Forts Martin Scott, Terret and McKavett, Tex.	.....	.....	.....	65.27	77.63	64.30	45.79	63.25	13	8
San Antonio, Texas.....	29 25 00	98 25 00	600	69.68	82.16	71.26	53.92	69.25	2	2
Fort Merrill, Texas.....	28 17 00	98 00 00	150 ?	73.88	83.17	72.18	56.27	71.37	1	4
Fort Ewell, Texas.....	28 05 00	98 57 00	200 ?	73.15	83.64	72.59	55.81	71.30	1	2
Corpus Christi, Texas.....	27 47 00	97 27 00	20	71.45	82.53	73.11	56.72	70.95	...	5
Fort Brown, Texas.....	25 54 00	97 26 00	50	74.73	83.58	74.62	62.09	73.75	5	5
Ringgold Barracks, Texas.....	26 23 00	99 02 00	200 ?	76.57	85.32	74.54	60.40	74.21	5	2
Fort McIntosh, Laredo, Texas.....	27 31 00	99 22 00	400 ?	75.84	85.91	73.84	57.36	73.24	5	2
Fort Duncan, Eagle Pass, Texas.....	28 42 00	100 30 00	800 ?	72.75	84.48	72.25	53.92	70.85	5	2
Fort Inge, Texas.....	29 09 00	99 47 00	845	68.67	81.18	68.81	52.10	67.69	4	3
Fort Lincoln, Texas.....	29 22 00	99 33 00	900 ?	67.78	81.04	68.47	54.85	68.03	.....	4
Fort Clark, Texas.....	29 17 00	100 25 00	1,000 ?	69.10	80.39	68.96	49.73	67.04	2	2
Fort Fillmore, New Mexico.....	32 13 00	106 42 00	3,937	63.72	81.32	64.27	46.62	63.98	3	2
Fort Webster, New Mexico.....	32 47 53	108 04 39	6,350	52.90	71.71	53.48	41.29	54.84	2	2
Fort Conrad, New Mexico.....	33 34 00	107 09 00	4,576	59.83	77.46	60.80	39.53	59.40	3	2
Albuquerque, New Mexico.....	35 06 00	106 38 00	5,032	55.90	74.91	57.33	37.15	56.32	2	5
Cebolletta and Laguna, New Mexico.....	35 03 00	107 14 00	6,000	52.50	75.20	56.80	35.98	55.12	2	2
Santa Fé, New Mexico.....	35 41 00	106 02 00	6,846	49.68	70.46	50.59	31.64	50.59	2	5
Fort Union, New Mexico.....	35 54 00	104 57 00	6,610	48.30	67.35	48.34	32.56	49.14	4	3
Fort Massachusetts, New Mexico.....	37 32 00	105 23 00	8,365	41.84	61.29	40.58	20.74	41.11	.....	4
Fort Defiance, New Mexico.....	35 44 00	109 15 00	7,200 ?	45.29	67.61	46.03	28.74	46.92	2	3
Fort Yuma, California.....	32 43 00	114 36 00	120	72.10	89.95	75.69	56.80	73.62	2	4
San Diego, California.....	32 42 00	117 14 00	150	59.97	71.26	64.43	52.29	62.00	4	3
Posts Del Chino and Jurupa, California.....	34 00 00	117 25 00	1,000 ?	61.01	72.44	65.78	53.89	63.28	1	4
Monterey, California.....	36 36 00	121 52 00	140	53.99	58.64	57.29	51.22	55.29	1	5

TABLE—Continued.

PLACES.	N. Lat.		W. Long.		Altitude above the sea.	Spring.	Summer.	Autumn.	Winter.	Year.	No. of years and parts of years observed.			
	°	'	°	'							Years.	Pt's y'rs.		
Fort Miller, California.....	37	00	00	119	40	00	402	62.78	85.48	66.36	49.35	66.00	1	4
San Francisco, California.....	37	48	00	122	26	00	150	54.51	57.33	56.83	58.86	54.88	2	5
Benicia Barracks, California.....	38	03	00	122	08	00	64	56.54	67.01	60.57	49.02	58.29	4	3
Sacramento and Camp Far West, California..	38	33	00	121	20	00	50	59.16	72.85	61.27	46.29	59.89	1	3
Fort Reading, California.....	40	30	00	122	05	00	674	59.88	80.00	62.35	46.12	62.09	2	2
Fort Jones, California.....	41	36	00	122	52	00	2,570	49.03	67.26	52.12	33.78	51.40	1	2
Fort Orford, Oregon.....	42	44	00	124	29	00	50	51.82	59.95	55.22	47.48	53.62	.....	4
Fort Vancouver, Oregon.....	45	40	00	122	30	00	50	51.88	65.65	53.54	39.54	52.65	2	5
Fort Dalles, Oregon.....	45	36	00	120	55	00	350	53.00	70.36	52.22	35.59	52.79	2	4
Fort Steilacoom, Washington Territory.....	47	10	00	122	25	00	300?	49.21	62.89	51.69	39.50	50.82	5	2
Great Salt Lake, Utah.....	40	46	00	112	06	00	4,351	51.73	75.92	.....	32.08	53.24	.....	4

NOTE 230.

The following amount of water falling in rain and snow is taken from the Army Meteorological Register for 1855.

	INCHES.					No. of years and parts of years observed.	
	Spring.	Summer.	Autumn.	Winter.	Year.	Years.	Pr'ty'rs.
Hancock Barracks, Maine.....	7.62	11.92	9.95	7.48	36.97	8	2
Fort Sullivan, Maine.....	8.88	10.05	9.85	10.61	39.39	7	3
Fort Preble, Maine.....	12.11	10.28	11.93	10.93	45.25	6	5
Fort Constitution, New Hampshire.....	9.03	9.21	8.95	8.38	35.57	9	5
Watertown Arsenal, Massachusetts.....	10.75	10.66	10.83	9.83	42.07	5	3
Fort Independence, Massachusetts.....	8.60	8.42	9.27	9.01	35.30	3	2
Fort Adams, Rhode Island.....	13.89	11.44	13.66	13.47	52.46	8	4
Fort Trumbull, Connecticut.....	10.90	10.65	13.16	10.98	45.69	3	1
Fort Hamilton, New York.....	11.69	11.64	9.93	10.39	43.65	13	1
Fort Columbus, New York.....	11.55	11.33	10.30	9.63	42.23	19	.....
West Point, New York.....	14.44	15.44	12.62	11.65	54.15	18	1
Watervliet Arsenal, New York.....	8.66	10.34	9.17	6.38	34.55	14	4
Plattsburg Barracks, New York.....	8.36	10.03	10.05	4.95	33.39	7	4
Madison Barracks, New York.....	8.94	10.23	12.51	8.10	39.78	7	4
Fort Ontario, New York.....	6.18	7.63	9.77	7.30	30.88	5	4
Fort Niagara, New York.....	6.87	9.81	8.66	6.41	31.77	8	4
Buffalo Barracks, New York.....	8.50	9.23	13.54	7.53	38.80	2	2
Allegheny Arsenal, Pennsylvania.....	9.38	9.87	8.23	7.48	34.96	17	2
Carlisle Barracks, Pennsylvania.....	9.05	9.67	7.68	7.61	34.01	3	4
Fort Mifflin, Pennsylvania.....	12.97	12.62	10.42	9.26	45.27	5	2
Fort McHenry, Maryland.....	11.13	11.04	10.52	9.31	42.00	18	1
Fort Severn, Maryland.....	9.65	12.00	16.17	10.79	48.61	1	2
Fort Washington, Maryland.....	12.57	12.84	10.22	9.39	45.02	1	2
Fort Monroe, Virginia.....	10.92	16.80	11.87	11.30	50.89	18	1
Fort Johnston, North Carolina.....	9.77	15.08	10.16	10.17	45.18	.....	.....
Fort Moultrie, South Carolina.....	6.83	15.52	16.32	7.34	46.01	1	1
Augusta Arsenal, Georgia.....	9.89	17.45	10.06	7.52	44.92	11	2
Oglethorpe Barracks, Georgia.....	6.78	3.66	4.51	8.05	23.00	1	2
Fort Marion, St. Augustine, Florida.....	13.45	23.50	7.21	9.17	53.33	3	2
Fort Shannon, Florida.....	5.90	10.54	9.56	5.80	31.80	1	4
Fort Pierce, (Capron,) Florida.....	12.49	21.49	9.71	4.99	48.68	3	.....
Key West, Florida.....	11.13	26.25	16.84	8.76	62.98	2	5
Fort Myers, Florida.....	8.34	16.59	15.35	7.37	47.65	6	4
Fort Brooke, Florida.....	11.07	30.91	11.96	8.32	62.26	4	2
Fort Meade, Florida.....	8.56	28.24	10.63	8.04	55.47	11	5
Cedar Keys, Florida.....	8.76	20.68	6.91	3.87	40.22	2	2
Fort Barrancas, Pensacola, Florida.....	4.10	22.35	11.94	10.11	48.50	2	1
Mount Vernon Arsenal, Alabama.....	12.86	18.69	13.71	11.72	56.98	3	8
Pass Christian and East Pascagoula, Mississippi.....	13.42	18.84	13.15	18.09	63.50	11	3
Fort Wood, Louisiana.....	.....	13.25	.....	.....	.....	.....	8
Fort Pike, Louisiana.....	16.13	17.30	15.60	11.60	60.63	1	3
New Orleans Barracks, Louisiana.....	16.70	23.61	18.96	12.65	71.92	1	3
Baton Rouge, Louisiana.....	11.29	17.28	9.62	12.71	50.90	6	9
Fort Jesup, Louisiana.....	15.08	19.14	12.48	15.40	62.10	6	6
Fort Towson, Indian Territory.....	13.68	10.94	9.74	11.49	45.85	9	1
Fort Washita, Indian Territory.....	15.55	14.36	12.23	8.94	51.08	10	7
Fort Smith, Arkansas.....	13.19	11.27	10.78	6.42	41.66	11	1
Fort Gibson, Indian Territory.....	12.48	13.03	9.93	6.66	42.10	13	4
Fort Scott, Missouri.....	11.38	9.68	9.25	6.15	36.46	17	2
Jefferson Barracks, Missouri.....	12.57	16.37	8.39	4.79	42.12	10	1
St. Louis Arsenal, Missouri.....	10.56	12.88	8.02	6.37	37.83	13	2
Detroit Barracks, Michigan.....	12.86	14.09	8.71	6.29	41.95	15	3
Fort Gratiot, Michigan.....	8.51	9.29	7.41	4.86	30.07	10	4
Fort Mackinac, Michigan.....	8.02	9.99	8.86	5.75	32.62	8	6
Fort Brady, Michigan.....	4.67	8.88	7.01	3.31	23.87	8	5
Fort Howard, Wisconsin.....	5.44	9.97	10.76	5.18	31.35	13	5
Fort Winnebago, Wisconsin.....	9.00	14.45	7.84	3.36	34.65	6	3
	5.58	11.46	7.63	2.82	27.49	7	

TABLE—Continued.

	INCHES.					No. of years and parts of years observed.	
	Spring.	Summer.	Autumn.	Winter.	Year.		
						Years.	P't yrs.
Fort Crawford, Wisconsin.....	7.63	11.87	7.90	4.00	31.40	7	3
Fort Atkinson, Iowa.....	12.22	20.43	4.82	2.27	39.74	1	2
Fort Des Moines, Iowa.....	6.86	10.93	4.90	3.87	26.56	.....	3
Fort Snelling, Minnesota.....	6.61	10.92	5.98	1.92	25.43	17	3
Fort Ripley, (Gaines,) Minnesota.....	6.31	12.62	8.42	2.13	29.48	4	2
Fort Leavenworth, Kansas.....	7.97	12.24	7.33	2.75	30.29	17	3
Fort Dodge, Iowa.....	7.92	8.15	8.19	3.06	27.32	1	2
Fort Kearney, Nebraska.....	10.80	12.05	3.82	1.31	27.98	5	2
Fort Laramie, Nebraska..	8.69	5.70	3.96	1.63	19.98	3	4
Fort Arbuckle, Indian Territory.....	8.15	8.98	8.90	4.54	30.57	4	2
Fort Belknap, Texas.....	7.09	6.31	6.85	1.75	22.00	2	2
Fort Worth, Texas.....	14.50	8.80	9.49	8.07	40.86	3	2
Phantom Hill, (Cedar Fork of Brazos,) Texas.....	3.84	4.08	7.30	2.00	17.22	1	2
Fort Chadbourne, Texas.....	8.52	10.46	8.99	3.91	31.88	2	2
Fort Graham, Texas.....	11.98	6.02	9.77	11.91	40.58	2	2
Fort Croghan, Texas.....	11.61	7.80	8.24	8.91	36.56	3	2
Forts Martin Scott, Mason, Terrett, and McKavett, Texas.....	5.86	6.69	8.05	2.67	23.27	4	7
San Antonio, Texas.....	8.63	10.22	7.57	7.35	33.77	2	2
Corpus Christi and Forts Ewell and Merrill.....	5.14	13.63	7.80	4.25	30.82	2	10
Fort Brown, Texas.....	3.97	9.26	15.08	5.34	33.65	5	1
Ringgold Barracks, Texas.....	4.49	7.10	6.31	3.05	20.95	5	2
Fort McIntosh, Texas.....	4.07	7.33	5.06	2.20	18.66	5	2
Fort Duncan, Texas.....	3.55	9.91	6.32	2.42	22.20	5	2
Fort Inge, Texas.....	6.06	11.06	6.99	3.88	27.99	4	3
Fort Clark, Texas.....	4.60	8.53	6.36	2.31	21.80	2	2
El Paso and Fort Bliss, New Mexico.....	0.70	3.56	5.25	1.70	11.21	.....	3
Forts Fillmore, Webster, and Thorn, New Mexico.....	0.75	4.44	3.30	0.74	9.23	2	3
Forts Conrad and Socorro, New Mexico.....	0.51	3.24	2.53	0.48	6.76	3	2
Albuquerque, New Mexico.....	1.10	5.45	2.07	0.80	9.42	2	4
Cebolleta, Laguna, New Mexico.....	1.23	1.91	5.87	3.04	12.05	2	1
Santa Fé, New Mexico.....	2.83	8.90	6.02	2.08	19.83	2	3
Las Vegas and Fort Union, New Mexico.....	2.47	9.62	5.12	2.03	19.24	3	3
Cantonment Burgwin and Fort Massachusetts, New Mexico.....	3.50	5.38	8.83	2.83	20.54	.....	6
Fort Defiance, New Mexico.....	2.91	6.41	4.67	2.65	16.64	2	2
Fort Yuma, California.....	0.27	1.31	0.86	0.80	3.24	2	3
San Diego, California.....	2.47	0.55	1.24	5.90	10.43	5	1
San Luis Rey, Rancho Del Chino, and Rancho De Jurupa, California.....	4.59	0.09	1.67	7.42	13.77	1	6
Monterey, California.....	4.43	0.21	1.65	5.91	12.20	1	5
Fort Miller, California.....	9.57	0.02	3.59	11.34	24.51	2	3
San Francisco, California.....	8.81	0.03	3.37	11.38	23.59	2	3
Benicia Barracks, California.....	6.40	0.01	2.65	7.56	16.62	4	3
Sacramento and Camp Far West, California.....	9.02	0.00	3.74	8.56	21.32	1	3
Fort Reading, California.....	11.30	0.39	4.89	12.44	29.02	2	2
Forts Humboldt and Jones, California.....	5.38	0.89	5.30	5.20	16.77	2	3
Fort Orford, Oregon.....	19.12	3.00	19.60	26.80	68.52	.....	4
Fort Vancouver, Oregon.....	9.28	6.23	10.30	19.69	45.50	2	5
Dalles of Columbia, Oregon.....	2.63	0.42	4.16	7.11	14.32	2	4
Fort Steilacoom, Washington Territory.....	11.19	3.85	15.20	21.51	51.75	5	2

CONTENTS,

REFERRING TO PARAGRAPHS NUMBERED.

	No.
Object of investigations	1
Means to procure observers.....	2
Names of observers	3
Value of results	4
Only means of deducing generalizations.....	5
Importance of meteorological charts.....	6
Comparative fluctuations of the barometer	7
Generalizations deduced from meteorological charts.....	8
Constant uniformity of nature.....	9
Theory—height to which air ascends before it begins cloud by cold of expansion, varies with the dew-point.....	10
Barometer falls under a forming cloud, and rises all round in its neighborhood—note on diurnal fluctuations.....	11
Cause of motion of storm clouds, different in different zones	12
Professor Pierce's objections answered	13
Theory founded on incontrovertible principles	14
Whirlwind theory of storms cannot be true	15
Why in the tornado or water-spout the cloud assumes the form of an inverted cone, and various other phenomena explained—with many proofs of inward motion of wind, and note on the manner of formation	16
Certificates that rains have frequently been produced artificially.....	17
Certificates that many farmers in Florida now produce rains every year, when they wish to plant corn	18
Volcanoes produce rain ; mud volcanoes	19
Plan for producing rain over the whole country.....	20
Why partial rains cannot take place immediately after a general rain	21
Ashes carried in all directions from volcanoes.....	22
Method of getting out of calms near northwest of Africa.....	23
Why are summer storms more local than winter storms?.....	24
Necessity of wide extended observations to answer this and various other questions—probability of success	25
Description of former experiments with nephelescope.....	26
Calculation of effect of latent caloric of vapor condensed in air	27
New experiments with double nephelescope made at the Smithsonian Institution	28
Object and success of the experiments	29
Description of double nephelescope	30
Mode of experimenting explained.....	31
Formula for calculating the expansion of air in the experiments, and the cold produced by expansion.....	32
Example of cold produced in dry air by expansion.....	33
Example of cold produced by expansion of condensed air discharged into rarefied air.....	34
Curious relation of cold of expansion to heat of condensation	35
Experiments, but slightly inaccurate, by sides of nephelescope heating the air during explosion, the time being short.....	36
Agitation of air in nephelescope very slight in explosion	37
Cloud not all dissipated in nephelescope till after equilibrium of temperature in nephelescope	38
Dew-point does not rise to temperature of air after explosion	39
Air in closed vessel in contact with water has its dew-point several degrees below the temperature of the water.....	40
Greater cold of expansion in moist air after standing a long time before discharge	41

Dew-point always below temperature of water at sea.....	No. 42
Evaporation of sea water the same as fresh water	43
Air not permeable to aqueous vapor, or at least to a very slight degree.....	44
Experiment to prove this fact	45
Vapor reaches upper regions of air only by up-moving currents of air, not by permeation.....	46
Thin clouds formed above tops of forming cumuli	47
Cumuli forming under cirrus thickens the cirrus.....	48
Tops of most lofty cumulus always rise above cirrus.....	49
How cirrus is formed out of tops of rain cloud.....	50
Every cloud is either a forming or dissolving cloud	51
A dissolving cloud cools the air in it, and produces a downward motion of the air and outwards below	52
If vapor permeated the air freely the torrid zone would be covered with eternal cloud.....	53
Why up-moving currents of air sometimes do not produce rain.....	54
Why it is much hotter in summer on the north side of the Himalayas than on the south side, and snow line higher.....	55
Cause of great heat in the Decan, India.....	56
Warmer on the west side the Andes, near the top, and snow line higher	57
Why the dew-point sometimes rises when the temperature sinks, and why the wind in some localities blows from a warm to a cold region	58
Cause of great rains just north of equator in summer	59
Cause of southwest monsoon in Atlantic in summer.....	60
Why the barometer stands above the mean at the outer borders of the trade winds.....	61
Remarkable phenomena at the Canary islands showing the same fact	62
Temperature of air in torrid zone below, about 80° , and at the top of the atmosphere would be about 173° colder if no latent caloric should be given out in the formation of clouds	63
When the dew-point is above 65° all the vapor is not condensed in the upward motion of air, even when the ascending air goes to the top of the atmosphere.....	64
Why this is so.....	65
Why the upper part of highest cumuli is flat as well as their base	66
Why cirrus is dense just before rain.....	67
Upper trade wind does not carry as much vapor to the tropics as the lower trade wind carries to the equator.....	68
Upper trade wind on descending to the earth in higher latitudes cannot produce rain, because it would be able to contain four times as much vapor below as above	69
Why the air is comparatively dry in the northern borders of the trade winds in the northern hemisphere, and why the surface of the sea is saltier there than at the equator—(note to 68)	70
Clouds cannot be formed by cold air from above coming down and mingling with warm air below.....	71
Absurd consequences of such a supposition	71
Hail is formed by drops of rain carried up into the region of congelation, and thrown out from the ascending current, frozen, or they freeze in the colder surrounding air in descending.....	72
No whirl in the hail cloud, unless very near the centre	73
What is the cause of the appearance of a hollow sometimes in a water-spout?.....	74
Heavy bodies not drawn up in tornadoes by electricity.....	75
Electricity not generated by condensing steam	76
Faraday's result confirmed by the author's experiments.....	77
What is the cause of atmospheric electricity?.....	78
Why have we no thunder in cold weather in winter?	79
Electricity the probable cause of the luminosity of meteoric rivers, or waterfalls	80
Luminosity of electricity in experiments with kites.....	81
Clouds of any considerable magnitude are never produced except by an up-moving currents of air.....	82
Why there is no rain where the trade winds are constant.....	83
Why the torrid zone is not covered with eternal cloud; up-moving columns producing rain, prevent cloud from forming all round them.....	84
Difficulty De Luc and Saussure had, to account for the formation of cloud when they discovered that forming cloud was warmer than surrounding air. De Luc concluded that clouds could only be formed by a decomposition of the air itself into water.....	85

	No.
Why no clouds are formed when the surface of the earth is much colder than the air above it.....	86
Clouds would have a thin, flat shape, if they were formed by mingling currents of air overlapping one another.....	87
An exception to this general rule.....	88
Leeward side of mountains warmer in time of snow than windward side near the top.....	89
No rain or snow at the poles of greatest cold in winter.....	90
In the region of constant rains, near the equator, the air at the surface of the earth is several degrees colder than on the outside of the rains.....	91
The barometer stands lower in the region of the rains, though the air there is colder below, because of the great quantity of latent caloric evolved into the air above by the condensation of the vapor into cloud.....	91
For the same reason, the barometer in Hindostan stands lowest during the rainy season; the air is then colder below, from the cooling effect of the rain drops descending from a region of cold above.....	92
The Himalaya <i>sine qua non</i> of the anomalous extent of the southwest monsoon in Hindostan.....	93
Cause of the very low barometer in high southern latitudes.....	94
Theoretical considerations why great rains should take place almost constantly in the borders of the frigid zones, especially the southern.....	95
Wind generally blows outwards from the poles near the borders of the ice.....	96
Frequently clear over the ice when it is snowing in its borders over the sea.....	97
Scoresby's account of the wind's blowing towards the ice at sea, and from the ice in the borders of the ice; with many examples by him.....	98
Facts showing that the barometer probably stands above the mean at the poles, as it certainly stands below the mean in the borders of the frigid zones.....	99
Reason why the barometer stands lower at the antarctic circle than at the arctic.....	100
Great prevalence of northern winds in high latitudes at sea, and also on land.....	101
Facts showing that the barometer stands higher near the southern pole than at the antarctic circle.....	102
Captain Wilkes' observations favor the same result.....	103
Barometer low, near the equator, in belt of rains, and high in borders of trade winds.....	104
Why the barometer stands low in the belt of rains, though the air at the surface of the sea is 6° colder.....	105
Three belts of low barometer and four belts of high barometer, including the two poles.....	106
The wind blows towards the belts of low barometer from the belts of high barometer.....	107
Barometer, contrary to common opinion, stands highest where the depth of atmospheric ocean is least, and <i>vice versa</i>	108
Why the winds do not blow constantly in the temperate zones towards the equator, as it would appear from the common explanation of the trade winds that they should.....	109
The upper trade winds do not come down in high temperate latitudes, as is generally believed, but in the belts of high barometer in the outer borders of the trade winds.....	110
Dew-point in belts of high barometer on the outer borders of the trade winds, according to the theory, low and variable; Humboldt's observations.....	111
Why the dew-point frequently falls before a great rain storm on the outside of the borders of the rain.....	112
But little found in books on the subject; Captain Wilkes' observations.....	113
The author sets out on a tour to the borders of the torrid zone to make observations on the dew-point in crossing the borders of the trade winds both by land and sea.....	114
Author's observations confirmatory of deduction from theory.....	115
Great fluctuations of the dew-point observed by the author from latitude 32° to 30° on the Mississippi river.....	116
Remarkable low dew-point in Atlantic in latitude 30½° to 31½°, when compared to the dew-point in lower or higher latitudes.....	117
Table of dew-points in and on each side of northern border of trade winds; observations by the author.....	118
The evolution of latent caloric in storms sufficient alone to account for the fall of barometer in storms, and its rise all around their borders.....	119
Barometer sinks more when it snows than when it rains, as the caloric of fluidity is then given out.....	120
The upper air previous to a storm contains a little less caloric, and after a storm much more caloric, for equal weights; Barral and Bixio's balloon ascension.....	121
The greater quantity of caloric in the upper air after a storm is radiated off into space before another storm comes on. In the normal state nearly equal quantities of caloric in equal weights of air at different heights.....	122

	No.
In storms the upper parts of the atmosphere become the lowest, and the lower parts take their place, and thus the common saying is verified—"a thunder storm purifies the air"	123
Nature of diathermanous envelopes	124
The upper air is cold, chiefly from the cold produced by rarefaction of air from diminished pressure in ascending currents	125
Temperature of space according to Poisson not correct—Pouillet's estimate nearly correct	126
Rule for finding cold produced in dry air, in experiments with double nephelescope	127
Rule for finding expansion of dry air	128
Rule to find expansion in moist air, in experiments with double nephelescope	129
Rule to find cold produced in moist air by expansion	130
Example of cold in moist air calculated	131
Remarks on the specific caloric of air	132
Experiments on <i>partially</i> moist air	133
Data assumed in calculating the specific caloric of atmospheric air under common pressure	134
Dew-point of air in contact with water for many days not as high as the temperature of the water	135
Specific caloric of air probably not so much as 0.267, if the tables of dew-point and latent caloric of vapor are correct	136
Example of calculating specific caloric of air	137
Specific caloric of air not obtained correctly by assuming that air in contact with water is completely saturated with vapor	138
Care necessary in repeating these experiments	139
Tables of experiments with double nephelescope	140
Laws of cooling from expansion in dry air	141
Temperature of the top of the atmosphere in different zones. Why the temperature of interplanetary space is lower than the top of the atmosphere at the poles in time of greatest cold, (note)	142
Laws of cooling by expansion in partially moist air. Air is prevented from cooling one degree for each $\frac{1}{100}$ of an inch of elastic force of vapor condensed	143
The temperature of space is near what Pouillet makes it—223° below zero of Fahr.—and is certainly colder than the top of the atmosphere, or there would be no rain or snow	144

DIRECTIONS FOR MARINERS.

Letter to the Secretary of the Navy, containing rules for the direction of the mariner when storms approach, with summary of theory	145
Phenomena indicating an approaching storm in Atlantic in middle latitudes	146
When the middle of the storm passes over the observer there will be a calm, with minimum barometer, and soon a change of wind to westward	147
How to know whether the centre of the storm in its motion towards the east passes to the north or south of the observer, and when its violence need be feared no longer	148
Of hurricanes in low latitudes—in what direction they move, and how to predict them and avoid them	149
Of sudden squalls—how to anticipate when they will be violent, and when not, in time to prepare for them in case they cannot be avoided	150
Of the pamperoes of the southeastern coast of South America—of the nature of squalls	151
Of the northers in the Gulf of Mexico	152
Of "the tornadoes"—improperly so called—on the western coast of Africa, and of storms in southern hemisphere	153
Of the belt of constant rains a little north of the equator in summer in the Atlantic, and why the wind blows towards that belt both on the north side of it and on the south	154
North of the belt of rains in the <i>regular</i> trades it cannot rain in open sea	155
How to distinguish a squall from a hurricane	156
The cause of violent gusts and short lulls in hurricanes, and of thick cloud down to the surface of the sea	157
The indications of the barometer, when understood, never fail as to the vicinity of a storm, especially in the torrid zone	158
Cause of low barometer near Cape Horn	159
Premature to lay down rules for storms in high southern latitudes	160
Four diurnal fluctuations of the barometer and their cause—(note to No. 11.)	

Acknowledged imperfection of the rules in the incipient state of the science.....	No. 161
Means pointed out of perfecting the science of meteorology, addressed particularly to commanders of American vessels	162
It is only when the dew-point is high that great storms can occur, as all storms are produced by steam power in the air.....	163
Table of the quantity of vapor in the air at different dew-points	164
Very simple method of taking the dew-point by means of the wet bulb.....	165
Great importance of observations on the dew-point at sea	166
In what direction do squalls move in the belt of high barometer about latitude 30° ?.....	167
When the dew-point is 20° or more below the temperature of the air, it does not rain on land: how is it at sea?.....	168
The manner in which cumuli form in the morning enables the observer to know whether it will rain during the day	169
Remarkable phenomenon of the sudden disappearance of cloud, and its cause.....	170
Striking instance of the general law, that the barometer rises on the outer borders of a great storm.....	171
Form to be observed by correspondents at sea	172
Numerous queries to be answered by observers at sea.....	173

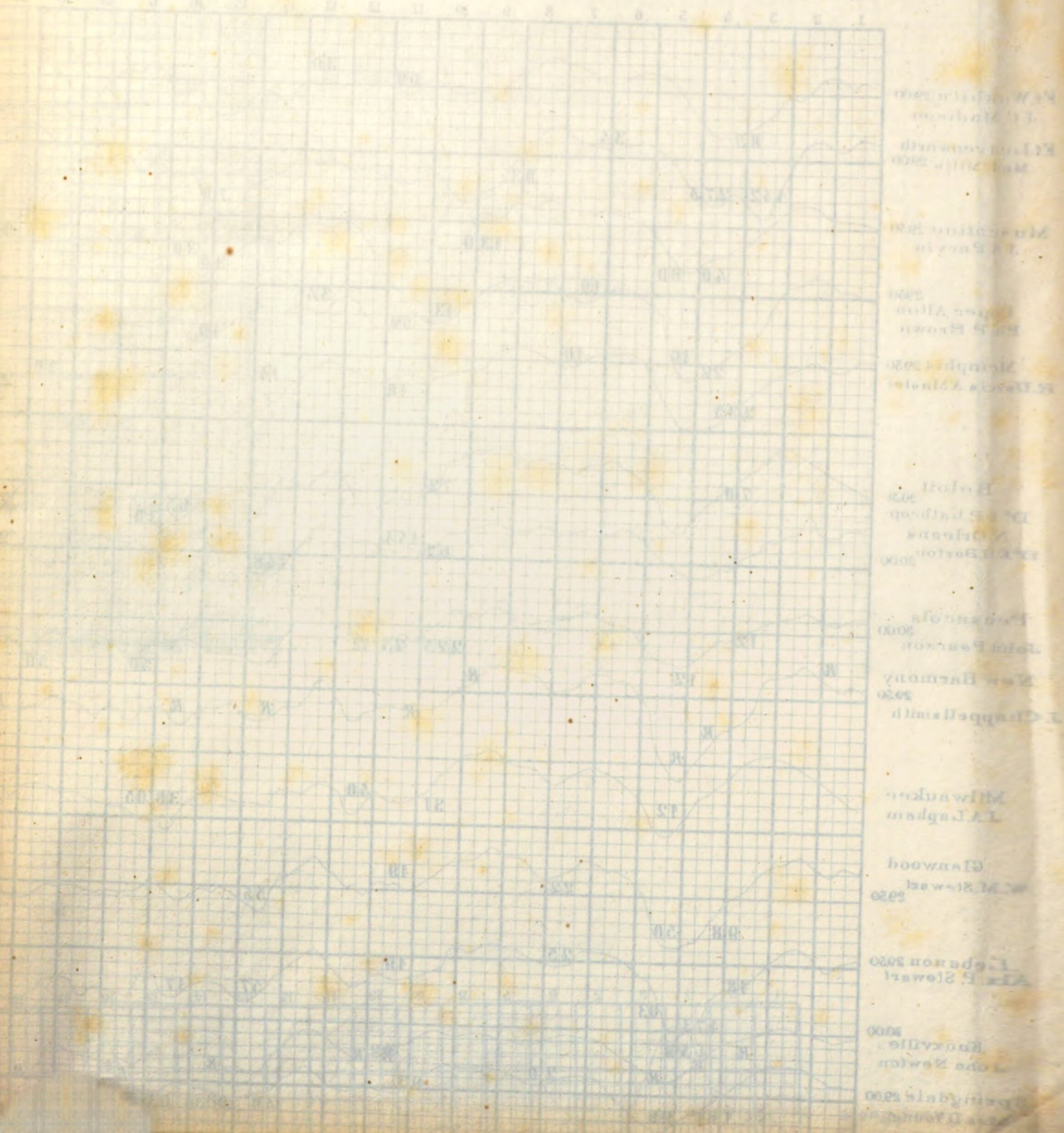
74. THEORY OF WINDS.

What the trade winds would be if there was no vapor in the air; preliminary principles laid down	175
How vapor modifies the action of the trade winds, causing high barometer at latitude 30°	176
Calculation of the depth of the hollow in the atmosphere at latitude 30° of high barometer, in consequence of the specific gravity of the air being greater on account of greater dryness.....	177
Velocity with which upper stratum of air runs from the belt of rains, near the equator, to latitude 30°	178
Why the barometer stands low at latitude 60° and high at the poles.....	179
In the belt of high barometer on land but little rain; not so at sea.....	180
The operation of the belt of high barometer on hurricanes while crossing it, in lengthening the north and south diameter	181
How the air which runs out below from the belt of high barometer gets back above, and why the wind in the temperate zones blows nearly from the west.....	182
The belts of high and low barometer, move in some degree annually with the sun	183
Irregularities produced by high mountains; the Andes.....	184
The Himalayas the cause of the monsoons	185
On the northwest monsoon of the Indian ocean, and the probability of its producing insulated storms, whirling as the hands of a watch.....	186
The "eye of the storm," and the effect of the return of the sun to the north.....	187
Deductions from the foregoing theory, and, especially, the wind does not blow inwards on all sides towards the desert of Cobi, or the desert would be flooded by rain	188
Strictures on the writings of Thomas Hopkins, of Manchester, with proofs of his plagiarism.....	189
New theory of land and sea breezes, according to Mr. Saigey	190
The reason why it seldom rains in the region of the regular trades, nor in the Sahara, nor in the desert of Cobi	191
Calculation made to show that mingling airs of different temperatures and dew-points cannot produce rain.....	192
Condensation of vapor not produced by the cold of mountain tops.....	193
The <i>Sirocco</i> does not originate on the heated desert of Africa, with hypothetical explanation, and many facts to show that great heat is produced round the borders of storms.....	194
Rivers among the Himalayas kept very cold by the evaporation of the dry air, and also in the hot desert between the sea of Aral and Hindoo Koosh	195
The <i>Bora</i> on eastern coast of the Gulf of Venice is probably produced on the principle of squalls by falling rain, and so of the rainy wind from the north at the head of the Gulf.....	196
The <i>Mistral</i> hypothetically explained.....	197
The <i>Kamsin</i> produced by the change of locality of the belt of high barometer	198
The <i>Harmatan</i> is a dry wind, not merely because it blows over the desert, but because it comes down from a great height, and finds no moisture at the surface of the earth to evaporate	199
Abundant rain takes place even in the Sahara where mountains occur, and also in the region of the trades where islands occur	200

	No.
Temperature of central parts of Pacific high, probably on account of the proximity of rain, and irregularity of the trades produced by the same cause	201
The monsoon of the Indian ocean furnishes proof that the wind blows not to heated land, but to the region of rain..	202
The wind always blows from the region of high barometer towards a region of low barometer, both above and at the surface of the earth, and, of course, towards rains	203
Graphic description of trade winds by Lieutenant Maury.....	204
Proofs of converging winds about 60° to 63° latitude south, and also of low barometer there.....	205
Proof of converging winds about Behring's Straits, and also of low barometer there.....	206
Storms about Cape Horn frequently produced by the dense heavy polar air pushed out below, and some of a similar character in the United States	207
A great increase of temperature during a calm night can only be accounted for by an approaching storm	208
The trade winds originate in the belt of high barometer, which corresponds to the annulus of high barometer round storms in the United States and elsewhere.....	209
Squalls seem to form an exception, where the wind blows out from the falling rain.....	209
Wind sometimes blows outwards from under a dissolving cloud.....	210
Ripples at sea seen by Humboldt explained, and also a cloud rolling down the side of a mountain.....	211
The red fog of Captain Wilkes explained.....	212
Most remarkable concatenation of causes producing rain	213
Changeable winds and fluctuations of the barometer produced entirely by the liberated caloric in the formation of cloud	214
The upper current of air in the northern temperate zone comes from north of west.....	215
The evaporation from land is poured down in rain east of the place where it is evaporated in the temperate zones....	216
More rain falls on land than on the ocean for given areas, especially on high lands	217
Air cannot rise in the torrid zone and carry its vapor with it above to the temperate zones.....	218
Barrell and Bixio's balloon ascent.....	219
Mosquera on New Grenada.....	220

NOTES.

Notes from 1 to 66, confirmatory of various principles adopted in this work	221
Notes 67 and 68. Sirocco, Mistral, and Bora.....	222
Note 69. Whistlecraft's storms of England probably move towards the southeast.....	223
Note 70. Rains at Owyhee	224
Note 71. Professor Loomis' great storm.....	225
Note 72. Professor Walker's remarks on Loomis' storm.....	226
Note 73. Synopsis of the whole theory	227
Mean temperature of 305 places according to Mahlmann	228
Mean temperatures, taken from the Army Meteorological Register of 1855	229
Quantities of rain at different places, from the Army Meteorological Register of 1855.....	230



Senate documents

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